Crew Members Fail to Realize That Shield Ring Installation Has Been Skipped—The crew members who aid in DPC cutting are an integral part of the overall task process, including the placement of the shield ring. They should be aware that the ring needs to be placed, and should question the crane operator if the crane operator tells them to begin the unbolting task when they have not participated in the placement process. In addition, the crew members should also be expecting to see a radiation protection worker check radiation levels and give them the "all clear" signal to approach the DPC. The crew members have a particular motivation to ensure that this is done, since the crew members (not the crane operator) are exposed to radiation if the shield ring is not installed. The unsafe action in this case is that they do not question the crane operator when told to begin the unbolting task. It is expected that their motivation for this unsafe action is most likely to be a reluctance to question the crane operator, who is above them in the operational hierarchy of the facility (i.e., the crane operator is essentially the foreman of the team). The crew member's deference to the crane operator's instruction would come from a belief that the crane operator was in charge and aware of the situation.

Because the crew members that are involved in DPC cutting process are the same crew members that assist in the shield ring installation process (i.e., preparing the crane, signaling the operator, etc.), the crew members need to miss this entire task for this event to occur. As a baseline value for this event, the same probability as crane operator fails to install shield ring can be used (0.01). However, the crew members would not be totally independent of the crane operator. The crew members could be distracted, or they could be starting a new shift and be convinced by the crane operator that they are ready to begin cutting preparation (i.e., a bias towards believing that the crane operator, who would generally be considered above them in the operations hierarchy, must be aware of the status of the operation). On the other hand, crew members would clearly expect to participate in this task and because it is important to their personal safety (i.e., they are the ones who are depending on the shielding) they are more cognizant of the operational status. Taking all of this into consideration, it is deemed that the level of dependence is low. For low dependence when a baseline HEP is 0.01, the adjusted HEP is taken from THERP (Ref. E8.1.26, Table 20-21, item (2)(a)) as follows:

Crew members fail to note that shield ring installation has been skipped = 0.05

Crew Members Fail to Notice That Shield Ring is Not In Place Prior to Approaching DPC—After the crew members are cleared to begin the cutting task, they gather the required tools and approach the DPC. The crew members would have performed this task many times before, and would have an image in their minds of how everything should look. The ring is a large and rather obvious device that the crew members would have to walk on or over in order to perform the unbolting. However, if the ring were not in place they would be exposed well before they got this close to it, so they would have to notice from some reasonable distance away. The crew members are carrying the tools they need, focusing on the performance of the task, and likely talking to each other about the performance of the task or having a casual conversation (since the work is not particularly difficult or challenging and they are not expecting any complications). The unsafe action results from the crew members not noticing that the configuration of the shield ring is not correct. Most likely, the crew members would have a bias that the operational conditions are in order and it is time to perform the task; the crew does not detect the differences in appearance (i.e., they see what they expect to see). To put this in a more colloquial context, this type of missed observation would be comparable to an individual walking out to a car and failing to see from a distance that the car has a flat tire. Noticing it when getting within a few feet of the car would be a failure in this case (the individual would already be "exposed").

Although there is no specific check that takes place when the crew begins setting up the cutting machine on the DPC, there is ample opportunity to notice that the shield ring is not in place. Rather than missing a check, it is more in the nature of failing to notice that something is not right. It would be similar to someone noticing a low tire on their car when they go out to start it. There are no failures in the primary quantification methods that reasonably fit this unsafe action, so it is necessary to provide a value based on expert judgment (ATHEANA). It is clear that some credit needs to be given for this since the crew members perform this task often and should recognize what the configuration should look like when they perform the task. However, in opposition to this, the crew begins operations carrying the necessary tools with them believing everything is in place. The HRA team believes that the failure is less than likely (0.5), but greater than unlikely (0.1). A value of 0.3 is selected.

Crew members fail to notice that shield ring is not in place prior to approaching DPC = 0.3

HEP Calculation for Scenario 1(a)—The events in the HEP model for Scenario 1(a) are presented in Table E6.7-4.

Table E6.7-4. HEP Model for HFE Group #7 Scenario 1(a) for 050-OpDPCShield2-HFI-NOW

Designator	Description	Probability
A	Crane operator fails to install shield ring	0.01
B	Crew members fail to realize that shield ring installation has been skipped	0.05
C	Crew members fail to notice that shield ring is not in place prior to approaching DPC	0.3

NOTE: DPC = dual-purpose canister; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C = 0.01 \times 0.05 \times 0.3 = 0.0002 \qquad \text{(Eq. E-38)}$$

E6.7.3.4.2.2 HFE Group #7 Scenario 1(b) for 050-OpDPCShield2-HFI-NOW

1. Crane operator installs shield improperly.
2. Radiation protection worker fails to check radiation levels OR radiation protection worker misreads radiation level OR radiation monitor fails.
3. Crew member fails to note that the shield ring is out of position before approaching the DPC.

Crane Operator Installs Shield Ring Improperly—The installation process is relatively simple and straightforward. Once the crew members attach the shield ring to the jib crane sling, the operator moves it over the DPC. The crew members help the operator to align the shield ring properly over the DPC using hand signals. The crew members signal the crane operator throughout the lowering process to ensure proper alignment. Although the operation is simple, the shield ring must have a close fit in order to completely block the annulus between the DPC and the STC to prevent radiation from escaping and exposing workers when they approach the DPC. If the shield ring is not exactly aligned, it could partially jam or hang up at a slight angle that would allow radiation to escape. The unsafe action is that the operator causes the shield ring to partially jam or hang up. Included in this is the implicit condition that the crane operator and crew members do not notice that the shield ring is jammed or hung up as they perform the task.

In this case, the crane operator is performing the shield installation task, but the shield ring is not seated properly. This is a very routine task, and is practiced often. Failures can be corrected without consequences since the operator has the opportunity to lift and place the shield ring as many times as necessary until the operator is satisfied that it is properly aligned. This can be represented by NARA GTT A5, adjusted by the following EPCs:

- GTT A5: Completely familiar, well designed, highly practiced, and routine task performed to highest possible standards by highly motivated, highly trained, and experienced personnel, totally aware of implications of failure, with time to correct potential errors. The baseline HEP is 0.0001.

- EPC 11: Poor, ambiguous, or ill-matched system feedback. This EPC addresses the issue that the crane operator views this operation from a distance. The maximum effect is ×4, which applies to a very difficult situation where visibility is poor, and visual and physical access if difficult. It is not believed that this case is this severe, but the full effect is still applied. The APOA is set to 1.0.

Applying the NARA HEP equation yields:

Crane operator installs shield ring improperly =

$$0.0001 \times [(4-1) \times 1 + 1] = 0.0004 \qquad \text{(Eq. E-39)}$$

Radiation Protection Worker Fails to Check Radiation Levels—The crane operator contacts the Health Physics Department before initiating the shield ring placement task, and awaits clearance that radiation levels are acceptable before ordering the crew members to unbolt the lift fixture. There are three potential ways that the radiation protection worker could fail to properly determine that the shield ring is not properly in place. First, the radiation protection worker could forget to perform the measurement; however, since the only reason the radiation protection worker was called to the WHF was to perform this task, the radiation protection worker would need to be distracted by something or someone to not perform this measurement. The radiation protection worker has performed this task a number of times in the past, and it is possible that the radiation protection worker could remember performing this task before and get confused and signal the operator that the levels are acceptable, believing that the radiation measurement has been performed. To put this in a more colloquial context, this type of omission would be comparable to an individual leaving their home or office without setting an alarm system. This individual performs this task every time they exit, and it has become second nature, so they cannot believe that they did not do it this time.

In this case, the unsafe action results from the radiation protection worker not checking radiation levels, after being called in specifically to perform this task. This can be represented by CREAM CFF E5, adjusted by the following CPCs with value other than 1.0.

- CFF E5: Action missed, not performed (omission). The baseline HEP is 0.03.
- CFP "Adequacy of Training/Preparation": This routine task is well trained, practiced, and performed quite frequently. The CPC for an execution task with adequate training and high experience is 0.8.
- CFP "Available Time": There is adequate time to perform this task and no significant time pressure. The CPC value for adequate time for an execution task is 0.5.

Applying these factors yields the following:

Radiation protection worker fails to check radiation levels = $0.03 \times 0.8 \times 0.5 = 0.02$

Radiation Protection Worker Misreads Radiation Levels—The second potential way that the radiation protection worker could fail to properly determine that the shield ring is not properly in place is by simply misreading the meter on the radiation gauge and believing the level is acceptable. Therefore, this failure is misreading the digital display on the radiation monitor. This can be represented by THERP (Ref. E8.1.26, table 20-11, item 1) (HEPs for EOCs in check-reading digital indicator displays).

Radiation protection worker misreads radiation level = 0.001

Radiation Monitor Fails—The radiation protection worker could also fail to properly determine that the shield ring is not properly in place due to a problem with the radiation monitor. The radiation monitor could give a false low reading as the result of a hardware failure. This is a mechanical rather than a human failure. From the Attachment C, Table C4-1, the failure rate for radiation sensors is approximately 2E−5/hour. It is expected that the monitor is used at least once each day. Using the equation for standby equipment ($0.5\lambda t$) yields:

Radiation monitor fails = $0.5 \times 2\text{E}{-5} \times 24 = 2.4\text{E}{-4}$

Crew Member Fails to Note Shield Ring Out Of Position Before Approaching DPC—The crew members, after being cleared to begin the cutting task, bring the required tools and approach the DPC. They have performed this task many times before, and they would have an image in their minds of how everything should look. Unlike the previous scenario, the ring is essentially in place and the misalignment is a more subtle deviation from the image they expect. Even so, if the ring were out of position they would be exposed well before they got close to it, so they would still have to notice from some reasonable distance away. The crew carries the tools they need, they are focused on the performance of the task, and likely talking to each other about the performance of the task or involved in casual conversation (since the work is not particularly difficult or challenging and they are not expecting any complications). The unsafe action is that they do not notice that the shield ring is out of position. The crew members would have a bias that the previous activities have been performed correctly, the shield ring is configured properly, and they are ready to proceed with their operations; any differences in appearance do not register (i.e., they see what they expect to see). To put this in a more colloquial context, this type of missed observation would be comparable to an individual walking out to a car and failing to see from a distance that the car has a flat tire. Noticing it when getting within a few feet of the car would be a failure in this case, since the person would already be exposed.

Although there is no specific check that takes place when the crew begins cutting preparations, there is ample opportunity to notice that the shield ring is not properly in place (i.e., that it is over the DPC, but out of position). Rather than missing a check, it is more in the nature of failing to notice that the operational conditions were not correct. It would be similar to someone noticing a low tire on their car when they go out to start their car. There are no failures in the primary quantification methods that reasonably fit this unsafe action, so it is necessary to provide a value based on expert judgment (ATHEANA). It is clear that some credit needs to be given for this action since the crew members perform this task often, and should recognize what the configuration should look like when they perform the task. However, in opposition to this, the crew begins operations on the DPC believing the shield ring is properly configured and they are focused on the task that they are about to perform. Taking all of this into consideration, the HRA team believes that the failure is less than likely (0.5), but greater than unlikely (0.1). A value of 0.3 is selected.

Crew members fail to notice that shield ring is out of position prior to approaching DPC = 0.3

HEP Calculation for Scenario 1(b)—The events in the HEP model for Scenario 1(b) are presented in Table E6.7-5.

Table E6.7-5. HEP Model for HFE Group #7 Scenario 1(b) for 050-OpDPCShield2-HFI-NOW

Designator	Description	Probability
A	Crane operator installs shield ring improperly	0.0004
B	Radiation protection worker fails to check radiation levels	0.02
C	Radiation protection worker misreads radiation level	0.001
D	Radiation monitor fails	2.4E−4
E	Crew member fails to note shield ring out of position before approaching DPC	0.3

NOTE: DPC = dual-purpose canister; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times (B + C + D) \times E = 0.0004 \times (0.02 + 0.001 + 2.4E{-4}) \times 0.3 = 3E{-6} \qquad \text{(Eq. E-40)}$$

E6.7.3.4.2.3 HEP for HFE 050-OpDPCShield2-HFI-NOW

The Boolean expression for the overall HFE (all scenarios) follows:

050-OpDPCShield2-HFI-NOW =
HFE 1(a) + HFE 1(b) =
0.0002 + 3E−6 = 0.0002

E6.7.3.4.3 Quantification of HFE Scenarios for 050-OpDPC-OVP01-HFI-NOW Operator Causes Overpressure when Filling/Flushing the DPC with Borated Water (DPC Only)

E6.7.3.4.3.1 HFE Group #7 Scenario 2(a) for 050-OpDPC-OVP01-HFI-NOW:

1. Operator pumps borated water at faster than acceptable rate.

2. Operator fails to notice pressure increase OR fails to stop operation given the pressure increase.

3. Pressure relief valve fails to operate OR pump motor fails to shut off upon overpressure.

Operator Pumps Borated Water at Faster Than Acceptable Rate—During preparation, the DPC is filled and flushed with water to prevent a crud burst when put into the pool. This step is straight forward, integral to the sampling and cutting, and on a checklist. The crew attaches two hoses to the DPC (one to the fill port and one to the drain port), via the quick disconnect ports and then starts the water flow according to procedures. The crew starts the cooling water feed pump to send borated pool water through the 1 in. treatment discharge piping into the DPC to cool it down. It is anticipated that this cool down would require one shift (8 hours) at minimum and up to 3 shifts (24 hours) to accomplish. Overpressurization can happen by setting the cooling water feed pump at or near its maximum rate of 20 gpm. The operator could make this error due to a perceived schedule pressure or because of some distraction.

The most likely scenario is that the crew rushes the process due to perceived schedule pressure and floods the DPC at a faster rate than the 8 to 24 hour timeframe. This would be accomplished by setting the cooling water feed pump at or near its maximum rate of 20 gpm.

This action is best represented by the CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

- CFF E1: Execution of wrong type performed (with regard to force, distance, speed, or direction). The baseline HEP is 0.003.

It is presumed that a second crew member is present during this task, but while that second crew member could note that the pumping rate is excessive, it is considered a dependent failure for them to not correct the situation since they are likely to depend upon the judgment of the initial operator. Based on Table 20-21 of THERP, for a baseline HEP of <.01 and medium dependence, the appropriate dependence value would be item (3)(a) or 0.15 (Ref. E8.1.26).

Operator pumps borated water at faster than acceptable rate = 0.003 × 0.15 = 0.0005

Operator Fails to Notice Pressure Increase

If the pump rate is set too high, then the overpressurization manifests itself fairly quickly (within the shift). There are alarms associated with overpressurization. The operator may be occupied with other tasks, but is located in the immediate vicinity of the DPC. The operator can fail to respond to the overpressure alarms because of distraction from other tasks or because the operator has inappropriately left the area for a prolonged period of time. If there is an overpressurization, it would most likely occur in the first hour or so of cooling, and the operator would have on the order of a minute or more to respond to the alarm before the DPC would be damaged.

The potential exists to monitor pressure during the fill/flush operation via either the pressure indicator on the inlet line to the DPC, or the indicator on the outlet line back toward the pool. This unsafe action can be represented by NARA GTT C1, adjusted for the following EPCs:

- GTT C1: Simple response to a range of alarms/indications providing clear indication of a situation (simple diagnosis required). The baseline HEP is 0.0004
- EPC 3: Time pressure. The full effect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOA is set at 0.1.
- EPC 13: Operator underload/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, a single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

Using the NARA HEP equation yields:

$$\text{Operator fails to notice pressure increase} = 0.0004 \times [(11-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.001$$

Operator Fails to Stop Operation Given Pressure Increase

If the operator responds to the alarm, it is possible that the operator fails to properly stop the operation. For example, the pressure can be misread or the operator could insufficiently turn down the flow and assume the alarm is malfunctioning. Alternately, the alarm could be responded to in an untimely manner and the operator could fail to stop the overpressurization before there is damage to the canister. If there is an overpressurization, it would most likely occur in the first hour or so of cooling and the operator would have on the order of a minute or more to respond to the alarm before the DPC is damaged.

This is an error of omission that can most closely be represented by CREAM CFF E5, adjusted by the following CPC's with values not equal to 1.0:

- CFF E5: Action missed, not performed (omission), including the omission of the last actions in a series. The baseline HEP is 0.03.
- CPC "Available Time": There is adequate time available. The CPC for an execution task with adequate time is 0.5.
- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields:

$$\text{Operator fails to stop operation given pressure increase} = 0.03 \times 0.5 \times 0.8 = 0.01$$

Pump Motor Fails to Shut Off Upon High Pressure Signal

The pump used to fill the canister receives a signal to shut off upon high pressure, but if the motor fails to shut off, an overpressure condition could result.

This is a mechanical failure to shut off of a motor, included in the PCSA active component reliability database provided in Attachment C, Table C4-1 as MOE-FSO.

$$\text{Pump motor fails to shut off} = 1.35E{-}8 = 1E{-}8$$

Pressure Relief Valve Fails to Operate Upon Overpressure

A pressure relief valve is provided on the pipe assembly that connects directly to the canister connection to protect against canister failure due to overpressure; however, failure of this valve could lead to an overpressure condition.

This is a mechanical failure of a pressure relief valve included in the PCSA active component reliability database provided in Attachment C, Table C1-4 as PRV-FOD.

$$\text{Pressure relief valve fails} = 6.5\ E{-}3 = 7E{-}3$$

HEP Calculation for Scenario 2(a)—The events in the HEP model for Scenario 2(a) are presented in Table E6.7-6.

Table E6.7-6. HEP Model for HFE Group #7 Scenario 2(a) for 050-OpDPC-OVP01-HFI-NOW

Designator	Description	Probability
A	Operator pumps borated water at faster than acceptable rate	0.0005
B	Operator fails to notice pressure increase	0.001
C	Operator fails to stop operation given pressure increase	0.01
D	Pressure relief valve fails to operate upon overpressure	7E−03
E	Pump motor fails to shut off upon high pressure signal	1E−08

NOTE: HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times [B + C] \times [D + E] =$$
$$0.0005 \times [0.001 + 0.01] \times [7E{-}3 + 1E{-}08] =$$
$$0.0005 \times 0.011 \times 7E{-}3 \qquad \text{(Eq. E-41)}$$

E6.7.3.4.3.2 HEP for HFE 050-OpDPC-OVP01-HFI-NOW

The human portion of the HEP quantification is 0.0005 × 0.011 and the mechanical portion is 7E−3.

With truncation of human portion for 1 team to 1E−5:

$$1E{-}5 \times 0.007 = 7E{-}08 \qquad \text{(Eq. E-42)}$$

E6.7.4 Results of Detailed HRA for HFE Group #7

The final HEPs for the HFEs that required detailed analysis in HFE Group #7 are presented in Table E6.7-7 (with the original preliminary value shown in parentheses):

Table E6.7.-7. Summary of HFE Detailed Analysis for HFE Group #7

HFE	Description	Final Probability
050-OpDPCShield2-HFI-COW	Operator causes exposure due to failure to install DPC shield ring	2E−4 (1E−02)
050-OpDPC-OVP01-HFI-NOW	Operator causes overpressurization of DPC during DPC Cutting	7E−8 (5E−03)
050-OpDPCShield3-HFI-NOW	Operator fails to properly shield DPC while removing canister lift fixture, leading to direct exposure	4E−04 [a] (1E−3)

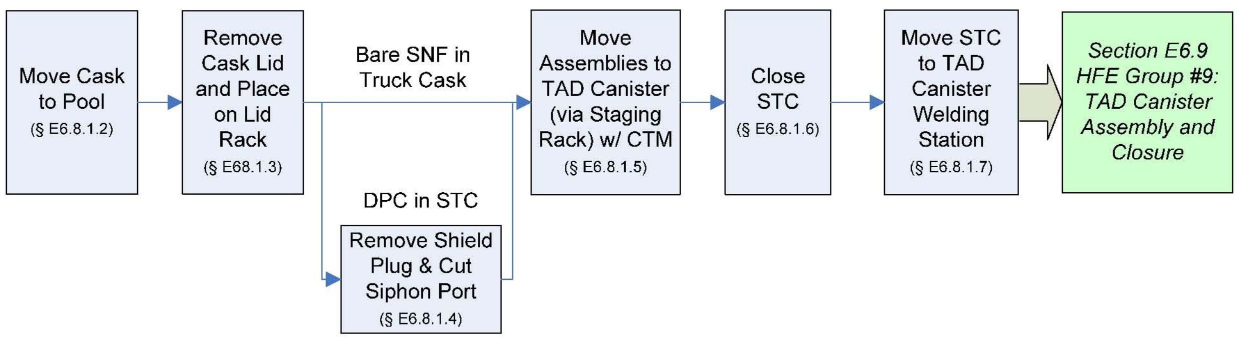
NOTE: [a]This value is taken from the detailed analysis for 050-OpDPCShield1-HFI-NOW (Table E6.5-6) because that HFE is identical to the HFE considered here (050-OpDPCShield3-HFI-NOW).

DPC = dual-purpose canister; HFE = human failure event.

Source: Original

E6.8 ANALYSIS OF HUMAN FAILURE EVENT GROUP #8: POOL ACTIVITIES: TRANSFER OF FUEL ASSEMBLIES INTO A TAD CANISTER

HFE group #8 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering the transfer of fuel assemblies into a TAD canister. The operations covered in this HFE group are shown in Figure E6.8-1. The process of transferring fuel assemblies into a TAD canister begins with fuel assemblies in either a truck cask at the SNF preparation platform or in a DPC in a STC at the DPC cutting station. Both types of the transportation casks have their lids bolted on. In this operation, the cask is transferred to the pool, the cask lid is removed, the spent fuel assemblies are transferred to a TAD canister (which is also in a STC), the TAD canister lid is emplaced, and the STC lid is bolted on. After the STC lid is bolted on, the STC containing the TAD is lifted out of the pool. This operation ends when the STC/TAD canister is stationed at the TAD canister closure station ready for TAD canister assembly and closure activities.



NOTE: § = section; CTM = canister transfer machine; HFE = human failure event; SNF = spent nuclear fuel; STC = shielded transportation cask; TAD canister = transportation, aging, and disposal.

Source: Original

Figure E6.8-1. Activities Associated with HFE Group #8

E6.8.1 Base Case Scenario

E6.8.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #8 activities:

1. The DPC is sitting in the DPC cutting area in a STC, with the STC lid bolted on. The DPC has no lid (but may have a shield plug) and is filled with borated water.

2. The SNF is sitting in the preparation station in a truck cask with the truck cask lid bolted on, and is located in a transportation cask handling frame.

3. The cask handling crane (200-ton) and auxiliary pool crane (20-ton) are in the pool area and have the following safety features:

   A. Upper limits—There are two upper limit marks: the initial is an indicator, and the final (which is set higher than the upper limit indicator) cuts off the power to the hoist. There is no bypass for the final limit interlock.

   B. There are end-of-travel interlocks on the trolley and bridge.

   C. There are speed limiters built into the motors.

   D. There is a weight interlock that cuts off power to the crane when the crane capacity is exceeded.

   E. There is a temperature interlock that cuts off power to the hoist when the temperature is too high. An indicator comes on before this temperature is reached.

   F. There is an indicator to signal the operators that the cask handling yoke is fully engaged, and an interlock (yoke engagement) that prevents the crane from moving unless and the yoke is either fully engaged or disengaged.

4. An STC with an empty TAD canister is positioned and ready in the Cask Preparation Area prior to the arrival of non-truck cask fuel assemblies. For all casks, the annulus between the TAD canister and the STC is pre-filled with demineralized water and sealed with a bladder on top to prevent borated water from seeping into the annulus.

5. The PWR fuel assemblies are significantly larger than the BWR fuel assemblies and should not be easily confused. Likewise, the staging racks for the PWR assemblies are noticeably taller than those for the BWR fuel.

6. The SNF transfer machine operator has the correct TAD canister loading plan (map) for a specific TAD.

7. The SNF transfer machine is located over the pool, and has the following safety features:

   A. Upper limits—There are two upper limit marks: the initial is an indicator, and the final (which is set higher than the upper limit indicator) cuts off the power to the hoist. There is no bypass for the final limit interlock.

   B. There are end-of-travel interlocks on the trolley and bridge.

   C. There is a speed limiter built into the motor.

   D. There is a weight interlock that cuts off power to the crane when the crane capacity is exceeded.

E. There is a temperature interlock that cuts off power to the crane when the motor temperature is too high. An indicator comes on before this temperature is reached.

F. There is an interlock which prevents the crane from moving the SNF too high.

8. The SNF transfer machine has five possible grapples:

   A. PWR lifting grapple #1

   B. PWR lifting grapple #2

   C. PWR lifting grapple #3

   D. BWR lifting grapple #1

   E. BWR lifting grapple #2.

9. The SNF transfer machine operator is located on the bridge over the pool, and can look down at the pool and see the operations. The operator also has a camera view of the pool operations.

Crane and SNF transfer machine operations in this operation are not part of a specific procedure outlined in the YMP documentation, but rather reflect the comparable standard operations in the nuclear industry.

The following personnel are involved in this set of operations:

- Crane operator
- Signaling crew member
- Verification crew member
- Radiation protection worker[14]
- Supervisor
- Nuclear engineer
- Quality control.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel. Personnel involved in pool operations wear the appropriate PPE.

E6.8.1.2 Movement of Cask to Pool

E6.8.1.2.1 Cask Movement to Staging Shelf in Pool

The transportation casks are moved to the staging shelf in the pool using the cask handling crane with the cask handling yoke; in the case of a truck cask, the cask is moved in the cask handling frame. In preparation for this step, the cask handling yoke is attached to the cask handling crane.

[14] The radiation protection worker, or health physicist, is not mentioned specifically in each step of this operation; however, there is always at least one radiation protection worker present during this step.

Crane Alignment to Cask— The operator positions the crane over the cask. The crane operator is on the floor in view of the crew members on either side of the cask. There is a signaling crew member next to the cask who uses hand signals to guide the operator's movements (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the cask, checking alignment of the second trunnion. The crew member signals the crane operator to stop, as required.

Engagement of Yoke Arms on Trunnions—Once the yoke is aligned, the signaling crew member signals the operator to close the yoke arms. Crew members check to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). The crane operator knows if the arms are sufficiently engaged on both sides by an indicator on the controller, and the signaling crew member signals the operator to raise the crane a slight amount to put pressure on the arms. The crane operator can see on the controller that the crane is bearing weight. Crew members verify that the yoke remains level. If the arms do adequately not engage on the initial attempt, either crew member signals the operator to stop, and the crane operator sets the cask down and opens the yoke arms to disengage. The signaling crew member then directs movement of the crane (again with hand signals) to compensate, and then signals the operator to close the yoke arms.

Cask Lifting and Movement to the Pool Staging Shelf – Once the cask is attached to the yoke, the signaling crew member signals the crane operator to lift the cask vertically. The crane operator lifts the cask vertically until it reaches the proper height for movement, basing this on a visual inspection, confirmed by hand signals from the signaling crew member. The proper height for movement is defined as roughly 6 in. above the highest obstacle in the movement path. This requires the crane operator to clear the cask from the platform before lowering the cask to movement height. The crane operator then begins to move the crane to the pool staging shelf, following the indicated safe load path marked on the floor to the pool ledge. The crane operator performs this task visually and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member on the opposite side of the cask of the signaling crew member who can only give the crane operator a signal to stop. Once the cask has cleared the pool ledge, the crane operator lowers the cask down onto the pool staging shelf. The crane operator can roughly align the cask on the shelf, but final alignment is directed by the signaling crew member, since the crane operator's view of the alignment in the pool may be obstructed. Once properly positioned, the signaling crew member signals the crane operator to finish lowering the cask. Finally, with the confirmation of the signaling crew member, the crane operator disengages the yoke and lifts the crane to proper moving height.

The crane operator is able to see crane movements inside the pool by looking over the edge of the pool and also via a camera fed to a monitor located on the crane controller.

E6.8.1.2.2 Move Cask to Position in Bottom of Pool

The transportation cask, or truck cask in a cask handling frame, is moved to position in the bottom of the pool using the cask handling crane with the cask pool handling yoke (with extension). In preparation of this step, the crew must remove the cask handling yoke from the cask handling crane, wash the yoke, attach the yoke extension piece, and then reattach the cask handling yoke. For this operation, the crane operator is standing at the ledge of the pool, there is a camera on the crane, and the camera monitor is located on the crane operator's controller.

Crane Alignment with Cask—The crane operator lowers the crane into position over the cask such that the yoke arms line up with the trunnions. The crane operator is positioned on the pool ledge looking down, and has a camera view of the crane operations on the crane controller.

Engagement of Yoke Arms on Trunnions—Once the yoke is aligned, the crane operator closes the yoke arms and checks to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). The crane operator knows if the arms are sufficiently engaged on both sides by an indicator on the controller and by the camera view. The crane operator raises the hoist to put a slight amount of pressure on the arms and then checks the controller to verify that the crane is bearing weight. The crane operator also verifies that the yoke remains level. If the arms do adequately not engage on the initial attempt the crane operator sets the cask down, opens the yoke arms to disengage, readjusts the yoke and then closes the yoke arms again.

Movement of Cask to Bottom of the Pool—Once the yoke is properly engaged, the crane operator lifts and moves the cask to clear the staging shelf, then lowers the cask to the proper height for movement. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path. The operator confirms the height visually via camera. The operator then moves the cask into position on the bottom of the pool, disengages the yoke, lifts the crane out of the pool and washes the yoke. Correct positioning of the cask is verified by quality control.

E6.8.1.3 Removal and Storage of the Cask Lid on the Lid Rack

The auxiliary pool crane is used with the long reach grapple adapter and lid lifting grapple to pick up and place the cask lid (truck cask or STC lid) on the appropriate lid stand. In preparation of this step, the crew members attach the lid lifting grapple with extension to the auxiliary pool crane. For this operation, the crane operator is standing at the ledge of the pool, there is a camera on the crane, and the camera monitor is located on the crane operator's controller.

Removal of Cask Lid Bolts—The cask lid bolts are remotely removed by personnel using underwater common tools and the auxiliary pool crane. The removed bolts are counted and verified before continuing.

Crane Alignment with Cask—The crane operator lowers the crane into position over the cask. The crane operator is positioned on the pool ledge looking down, and has a camera view (underwater) of the crane operations on the crane controller. Once positioned, the crane operator engages the lid lifting grapple to the lid adapter on the cask lid. There is an indicator to verify engagement.

Vertical Lift of the Lid—Once the grapple is engaged, the crane operator begins to raise the cask lid out of the pool. Once the lid is out of the pool, a crew member washes off the grapple and lid, and the crane operator lowers the lid to the proper movement height based on visual inspection. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path. The crane operator then moves the lid to the appropriate lid stand in the staging area, following the indicated safe load path marked on the floor.

E6.8.1.4 Removal of the DPC Shield Plug and Cutting of the Siphon Port (DPC in STC Only)

The crane operator uses the auxiliary pool crane with the appropriate extensions to lift the DPC shield plug above the siphon tube shear tool (approximately 1 to 2 ft). A crew member uses the siphon tube shear tool to cut the siphon tube. The crane operator then proceeds to move the shield plug to the staging area. The siphon tube shear tool is like an arm that swings over the STC and cuts the siphon tube. The siphon tube is taller than the STC and cannot impact it.

E6.8.1.5 Movement of SNF Assemblies to TAD Canister (via Staging Rack) with SNF Transfer Machine

The TAD canister loading plan is prepared before the TAD canister is placed into the pool and the loading sequence is verified by both Nuclear Engineering and quality control. The TAD canister cannot be placed into the pool until all the SNF assemblies identified in the loading plan are in the pool and ready for transfer into the TAD canister. A full TAD canister contains 21 PWR assemblies or 44 BWR assemblies. A DPC has more fuel assemblies than can fit into one TAD canister. For bare SNF arriving in truck casks, 5 truck casks full of BWR fuel assemblies or 9 truck casks full of PWR fuel assemblies are needed to fill one TAD canister. Section E6.1 provides a more detailed explanation of "campaigns." Movement of the SNF assemblies with the SNF transfer machine is described in the following sections:

E6.8.1.5.1 Preparation for TAD Canister Loading

All the fuel assemblies in the TAD canister loading plan must be present in the staging rack before the TAD canister/STC unit is placed in the pool. Once all the SNF assemblies are staged in the staging racks, then the TAD canister/STC unit is placed into the pool as follows:

E6.8.1.5.1.1 Movement of SNF Assemblies to Storage Rack

The SNF transfer machine is used with the BWR lifting grapple #1 or #2, or PWR lifting grapple #1, #2, or #3 to move the SNF assemblies from a DPC or a truck cask into the SNF staging rack.

The SNF transfer machine operator attaches the correct fuel assembly grapple to the SNF transfer machine (crane like) and then position the grapple over the SNF assembly to be moved. Once in position, the operator engages the grapple (verified by indicator and visual inspection via camera) and lifts the assembly to the proper height for movement under the water. The operator then moves the SNF transfer machine laterally to position it over the staging rack. Once positioned, the operator lowers the assembly onto the rack, disengages the grapple, and lifts the SNF transfer machine.

E6.8.1.5.1.2 Movement of STC and TAD Canister into the Pool

Once all the fuel assemblies necessary to fill a TAD canister are in the staging rack, the crane operator uses the cask handling crane with cask handling yoke and long reach adapter to move the empty STC/TAD canister into the pool. The annulus of the STC/TAD canister is pre-filled with demineralized water and sealed with a bladder. For this operation, the crane operator is standing at the ledge of the pool; there is a camera on the crane and the corresponding monitor is located on the crane operator's controller.

Crane Alignment to Cask—The operator positions the crane (with cask handling yoke and extension) over the cask. The crane operator is positioned on the building floor in view of the crew members on either side of the cask. There is a signaling crew member next to the cask using hand signals to guide the operator's movements (no hardwired or wireless communication system is used) to position the woke on the first trunnion. A verification crew member on the opposite side of the cask checks the alignment of the second trunnion. Once this is achieved the crew member signals the crane operator to stop.

Engagement of Yoke Arms on Trunnions—Once the yoke is aligned, the signaling crew member signals the operator to close the yoke arms. Crew members check to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). The crane operator knows if the arms are sufficiently engaged on both sides by an indicator on the controller, and the signaling crew member signals the operator to raise the crane a slight amount to put pressure on the arms. The crane operator can see on the controller that the crane is bearing weight. Crew members verify that the yoke remains level. If the arms do adequately not engage on the initial attempt, either crew member signals the operator to stop. The crane operator sets the cask down and opens the yoke arms to disengage. The signaling crew member then directs the movement of the crane with hand signals, and then signals the operator to close the yoke arms.

Lift and Move Cask to Pool Bottom —Once the cask is attached to the yoke, the signaling crew member signals the crane operator to lift the cask vertically. The crane operator lifts the cask vertically until it reaches the proper height for movement (based on a visual inspection) that is confirmed by hand signals from the signaling crew member. The proper height for movement is defined as roughly 6 in. above the highest obstacle in the movement path. The crane operator then begins movement to the pool, following the indicated safe load path marked on the floor to the pool ledge. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member on the opposite side of the cask as the signaling crew member which can only give the crane operator a signal to stop. Once the cask has cleared the pool ledge and is roughly over the portion of the pool where the TAD canister is staged, the crane operator lowers the cask down to the pool bottom. The crane operator can roughly align the cask by eye, but final alignment is done using the camera view. Once the TAD is correctly placed, the crane operator disengages the yoke, lifts the crane out of the pool and washes the yoke. Correct positioning of the cask is verified by quality control.

E6.8.1.5.2 Move SNF Assemblies to TAD Canister with SNF Transfer Machine

The SNF transfer machine is used with BWR lifting grapple #1 or #2 or PWR lifting grapple #1, #2, or #3 to move the SNF assemblies from a DPC, a transportation cask, or the SNF staging rack into a TAD canister.

The SNF transfer machine operator attaches the correct fuel assembly grapple to the SNF transfer machine and then positions the grapple over the SNF assembly to be moved. Once in position, the operator engages the grapple (verified by indicator and visual inspection via camera) and lifts the assembly to the proper height for movement underwater. The operator then moves the SNF transfer machine laterally to position it over the TAD canister, lowers the assembly into the TAD canister, disengages the grapple and lifts the SNF transfer machine. For DPCs, the fuel assemblies are moved through the DPC unloading bay gate that is normally open.

The SNF transfer machine operator has a loading plan (map) for the TAD canister that indicates the serial number of the fuel assembly to be placed in each position of the TAD canister. When a fuel assembly is placed in the TAD canister, the SNF transfer machine operator documents the serial number and both operator and the quality control personnel verify the serial number and positioning.

This operation repeats this process until the TAD canister is full with 21 PWR assemblies or 44 BWR assemblies.

E6.8.1.6 Closure of an STC

E6.8.1.6.1 Installation of TAD Canister Lid

The auxiliary pool crane is used with the long reach grapple adapter to pick up the lid lifting grapple and place the TAD canister lid onto the TAD canister. In preparation of this step, the crew members attach the lid lifting grapple, with extension, to the auxiliary pool crane. For this operation, the crane operator is standing at the ledge of the pool; there is a camera on the crane and the corresponding monitor is located on the crane operator's controller.

The crane operator uses the auxiliary pool crane to retrieve the TAD canister lid. The crane operator moves the crane to the lid, engages the grapple (indicator), then lifts the lid to proper position for movement. The operator then moves the lid over the pool and lowers it into position over the TAD canister. The operator is positioned on the floor at the ledge of the pool. There is a camera underwater that the crane operator can use to verify positioning. Once positioned, the crane operator disengages the lid lifting grapple and uses an indicator to verify disengagement.

E6.8.1.6.2 Installation of STC Lid

The auxiliary pool crane with the long reach grapple adapter is used to pick up the lid lifting grapple and place the STC lid onto the STC.

Once the lid lifting grapple is disengaged from the TAD canister lid, the crane operator lifts the crane and washes off the grapple and long reach adapter. The operator then moves the auxiliary pool crane over to the STC lid rack, engages the grapple to the STC lid (indicator), and lifts the STC lid to the proper height for movement. The crane operator moves the lid over the pool in position over the cask and then lowers the lid onto the STC. The operator assesses the alignment visually with the aid of a camera. Once in place, the crane operator disengages the grapple from the lid and lifts the crane. The operator lifts the crane and washes the grapple and adapter.

E6.8.1.6.3 Bolting STC Lid

Using at least four bolts, the lid is bolted to the STC by personnel using common underwater tools and the auxiliary pool crane. This step is verified on a checklist.

E6.8.1.7 Movement of an STC to the TAD Canister Welding Station

E6.8.1.7.1 STC Lifting to the Staging Shelf

The STC is moved to the staging shelf in the pool using the cask handling crane with the cask pool handling yoke and crane extension. In preparation for this step, the cask pool handling yoke, with extension, must be attached to the cask handling crane. For this operation, the crane operator is standing at the ledge of the pool; there is a camera on the crane and the corresponding monitor is located on the crane operator's controller.

Crane Alignment to Cask—The crane operator positions the crane over the cask. The crane operator is standing at the ledge of the pool looking down, and has a camera view of the crane operations from the controller. The crane operator lowers the crane into position so that the yoke arms are lined up with the trunnion.

Yoke Arm Engagement on Trunnions—Once the yoke is aligned, the crane operator closes the yoke arms. The operator checks to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). An indicator on the controller lets the crane operator know when the arms are sufficiently engaged and the operator raises the crane a slight amount to put pressure on the arms. The crane operator can see on the controller that the crane is bearing weight. The operator verifies that the yoke remains level. If the arms do adequately not engage on the initial attempt the operator stops, sets the cask down, opens the yoke arms to disengage, readjusts the yoke, and then closes the yoke arms.

Cask Movement to the Staging Shelf in the Pool—Once the yoke is properly engaged, the crane operator moves the cask into position on the staging shelf of the pool, lowers the cask onto the shelf, disengages the yoke, and lifts the crane out of the pool.

E6.8.1.7.2 Cask Pool Handling Yoke Washing and Placement on the Cask Pool Handling Yoke Stand

Once the cask pool handling yoke is disengaged from the STC, the crane is lifted out of the pool. The yoke (with extension) is washed over the pool using the wash lance. The crane operator uses the cask handling crane to place the cask pool handling yoke extension onto the cask pool handling yoke stand, following the indicated safe load path marked on the floor. A crew member then reattaches the cask handling yoke to the cask handling crane.

E6.8.1.7.3 Lifting the STC Out of the Pool

The STC is lifted out of the pool using the cask handling crane with the cask handling yoke. In preparation for this step, the cask handling yoke is attached to the cask handling crane.

Aligns Crane to STC – The crane operator positions the crane over the STC. The operator is positioned at the ledge of the pool looking down, and has a camera view of the crane operations from the controller. The crane operator lowers the crane into position so that the yoke arms are lined up with the trunnion.

Yoke Arm Engagement on Trunnion and Lifting of STC Out of the Pool – Once the yoke is aligned, the crane operator closes the yoke arms. The operator checks to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm), with the use of an indicator on the controller. The crane operator raises the crane a slight amount to put pressure on the arms and can see on the controller that the crane is bearing weight. The operator verifies that the yoke remains level. If the arms do adequately not engage on the initial attempt the operator stops the process, sets the cask down, disengages the yoke arms by opening them, readjusts the yoke, and then closes the yoke arms. Once the yoke is properly engaged, the crane operator lifts the cask vertically out of the pool. The crane operator is able to see crane movements inside the pool by looking over the edge of the pool and also via a camera feed to a monitor located on the controller.

E6.8.1.7.4 Wash Lifting Yoke and Exterior of STC over the Pool

While the STC is suspended over the pool, a crew member washes the cask handling yoke and the exterior of the STC over the pool using the wash lance. The crew is cognizant of the boron pool concentration during this operation. The wash lance has a trigger mechanism that won't stay on unless the crew member is pressing on the trigger.

E6.8.1.7.5 Move STC to the TAD Canister Welding Station

The operator lowers the cask to the proper height for movement (i.e., 6 in. above the highest obstacle in the movement path) and then moves the STC to the TAD canister welding station, using the cask handling crane with the cask handling yoke. The operator visually follows the indicated safe load path marked on the floor, and also receives confirmatory hand signals from the signaling crew member. Once at the welding station, a crew member opens the hinged platform to allow the STC to pass through. Once in proper position in the weld station, the crane operator lowers the cask to the floor of the welding station and disengages the yoke. The crew member closes the hinged platform so there is a proper working platform around the STC.

E6.8.2 HFE Descriptions and Preliminary Analysis

This section defines and screens the HFEs that are identified for the base case scenario, that can affect the probability of initiating events occurring, and that could lead to undesired consequences. Descriptions and preliminary analysis for the HFEs of concern during pool activities are summarized in Table E6.3-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

Table E6.8-1. HFE Group #8 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
Crane Drops	*Operator Drops Cask or Object onto Cask/Fuel Assembly*: During the pool activities, several objects are moved, including: the cask, the fuel assemblies, the cask lid, the DPC shield plug, etc. Each of these lifts could result in a drop and damage to the fuel/canister.	19, 20, 21, 22, 23, 24, 30	N/A[a]	There are several lifts in this operation, including several lifts of the cask itself. These lifts of casks and heavy objects can all potentially result in a drop. Crane drop related HFEs were not explicitly quantified because the probability of a crane drop due to human failure is incorporated in the historical data used to provide general failure probabilities for drops involving various crane and rigging types. Documentation for these failures can be found in Attachment C. Note: Except for the movement from the pool shelf to the pool bottom, the cask lid is bolted with at least four bolts for each cask lift in this operation.
Drops from SNF Transfer Machine	*Operator Drops Fuel Assembly*: During the pool activities, many fuel assemblies are moved using the SNF transfer machine. Each of these lifts could result in a drop and damage to the fuel/canister.	22	N/A[a]	There are several fuel assembly lifts in this operation performed using the SNF transfer machine. These lifts of fuel assemblies can all potentially result in a drop. Historical data is used to quantify the probability of dropping a fuel assembly with the SNF transfer machine. Documentation for this failure can be found in Attachment C.
050-OpTCImpact06-HFI-NOD	*Operator Causes an Impact between the Cask and an SSC during Movement between the Pool Ledge and the Outside of the Pool*: In this step, the DPC/STC and SNF/TC are moved to the pool ledge from the DPC cutting station or SNF preparation platform (respectively), and the TAD canister/STC unit is moved from the pool ledge to the TAD canister closure station outside the pool. In terms of failure modes and conditions, these two movements are identical. During this movement, the crane operator can cause the cask to collide with an SSC, such as the side of the pool or the TAD canister closure station, DPC cutting station, or SNF preparation platform.	19, 20, 24	3E−03	In this step, the DPC/STC and SNF/TC are moved to the pool ledge from the DPC cutting station or SNF preparation platform (respectively), and the TAD canister/STC unit is moved from the pool ledge to the TAD canister closure station outside the pool. For crane operations in this step, there are three observers with clear visibility, the operations are simple, the travel distances are short, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a very regular (daily) basis. There are no interlocks to prevent this error. The dominant contributors to the impact of a cask include the following: • Crane moved outside its safe load path (e.g., operators cut corners) • Crane moved in wrong direction • Operator failed to maintain proper vertical and horizontal distance between cask and SSCs during crane operations • Bridge or trolley impacts end stop. The operator must manually maintain movement within the safe load path. It is not unlikely that the operator would stray slightly from that path or that an object would be slightly within that path. However, the crane operations are very slow and within clear, direct view of three observers. This operation is very similar to and has the same failure modes as operator causes an impact between cask and SSC during upending and removal (050-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2), and was thus assigned the same preliminary value with the same rationale: the preliminary value was chosen based on the determination that this failure is "highly unlikely" (one in a thousand or 0.001) and was adjusted because there are several ways for an impact to occur (×3).
050-OpTipOver002-HFI-NOD	*Operator Causes Cask to Tip Over during Movement between Pool Ledge and Outside the Pool*: In this step, the DPC/STC and SNF/TC are moved to the pool ledge from the DPC cutting station or the SNF preparation platform (respectively), and the TAD canister/STC unit is moved from the pool ledge to the TAD canister closure station outside the pool. In terms of failure modes and conditions, these two movements are identical. During this movement, the crane operator can catch the ledge of the pool while moving the cask into or out of the pool. If the crane operator and crew members do not notice, the cask can start to tipover. If a trunnion or yoke arm fails due to the lateral force from the tipping, then the cask can fall over.	19, 20, 24	3E−03	In this step, The DPC/STC and SNF/TC are moved to the pool ledge from the DPC cutting station or SNF preparation platform, and the TAD canister/STC is moved from the pool ledge to the TAD canister closure station outside the pool. During this movement, the cask can be tipped over if it catches the ledge of the pool as the cask is moved onto the pool shelf. Unlike other cask tipover events (050-OpTipover001-HFI-NOD), the most likely cause of this tipover is that the crane operator catches the edge of the pool while lowering the cask into the pool or taking the cask out of the pool, and the crew members and crane operator fail to notice before the cask tips over. This failure requires the crane operator and the two crew members to be inattentive. This operation was given the same preliminary value as cask impact (050-OpTCImpact06-HFI-NOD) because it has the same basic cause and failure modes of inattention of the crane operator and the crew members. This preliminary value is considered particularly conservative because there is time (on the order of 30 to 90 seconds) for one of the three workers to notice and correct the error. The error is easy to correct, is very visible and may also require a mechanical failure to result in an actual tipover.
050-OpTCImpact07-HFI-COD	*Operator Causes an Impact Between Cask and SSC during Cask Movement between Pool Shelf and Pool Bottom*: In this step, The DPC/STC and SNF/TC are moved from the pool ledge to the pool bottom and the TAD canister/STC is moved from the pool bottom to the pool ledge. In terms of failure modes and conditions, these two movements are identical. During cask movement, the crane operator can cause the cask to collide with an SSC, such as the side of the pool, the staging rack or a staged STC.	21	6E−03	In this step, the DPC/STC and SNF/TC are being moved from the pool ledge to the pool bottom and the TAD canister/STC unit is moved from the pool bottom to the pool ledge. This operation is very similar to and has the same failure modes as operator causes an impact between cask and SSC during movement to pool shelf (3E−3, 050-OpTCImpact06-HFI-NOD), but this operation is done from the pool ledge looking over into the pool. The crane operator also has a camera view by which to observe the operations. The preliminary value was adjusted (×2) to account for visual distortion due to parallax effects and the camera view.

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Table E6.8-1. HFE Group #8 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpTipOver004-HFI-COD	*Operator Causes Cask to Tip Over during Cask Movement between Pool Shelf and Pool Bottom*: In this step, the DPC/STC and SNF/TC are moved from the pool ledge to the pool bottom and the TAD canister/STC is moved from the pool bottom to the pool ledge. In terms of failure modes and conditions, these two movements are identical. During this movement, the crane operator can catch the ledge of the pool shelf while moving the cask onto or off of the pool shelf. If the crane operator and crew members do not notice, the cask can start to tipover. If a trunnion or yoke arm fails due to the lateral force from the tipping, then the cask can fall over.	21	6E−03	In this step, The DPC/STC and SNF/transportation cask are moved from the pool ledge to the pool bottom and the TAD canister/STC unit is moved from the pool bottom to the pool ledge. This operation is very similar to and has the same failure modes as operator causes a cask to tip over during movement to pool shelf (3E−3, 050-OpTipover002-HFI-NOD), but this operation is done from the pool ledge looking over into the pool. The crane operator also has a camera view by which to observe the operations. The preliminary value was adjusted (×2) to account for visual distortion due to parallax effects and the camera view.
050-OpFuelImpact-HFI-NOD	*Operator Impacts Fuel Assembly During Transfer*: If the spent fuel transfer machine operator does not lift the fuel assembly high enough or does not follow a clear path during fuel assembly transfer, the operator can impact and damage the fuel assembly.	22	N/A	If the SNF transfer machine operator does not lift the fuel assembly high enough or does not follow a clear path during fuel assembly transfer, an impact can occur that damages the fuel assembly. This failure event was screened out by the WHF analysts because: (1) criticality due to impact was screened out based on pool boration, criticality in this case is only an issue if it is accompanied by a loss of boration (screened out in Table 6.0-2 of the main report); (2) gaseous radiation release due to impact is bounded by the drop event addressed above. This HFE was omitted from the HRA analysis.
Improper Boration	*Operator Fails to Maintain Proper Boron Concentration*: If the operators fail to maintain the proper boron concentration, then it can result in a potential criticality.	N/A	N/A	If the operators fail to maintain the proper boron concentration, then it can result in a potential criticality. This failure event was screened out by the WHF analysts and is not part of this HRA; Table 6.0-2 of the main report provides the screening justification. This HFE was omitted from the HRA analysis.
Fuel Transpose	*Operator Misloads TAD Canister*: The SNF transfer machine operator can misload the TAD canister by failing to follow the loading map, transposing two or more fuel assemblies, or otherwise loading the TAD canister with the wrong fuel assemblies. This failure has possible criticality and thermal implications.	N/A	N/A	Misloading a TAD canister with the wrong fuel assemblies or transposing fuel assemblies has no criticality consequence (Table 4.3-1) and was therefore omitted from analysis.

NOTE: [a]HRA value replaced by use of historic data (Attachment C).

DPC = dual-purpose canister; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; HRA = human reliability analysis; N/A = not applicable; SNF = spent nuclear fuel; ssc = structure, system, or component; SSCs = structures, systems, and components; STC = shielded transfer cask; TC = transportation cask; TAD = transportation, aging, and disposal.

Source: Original

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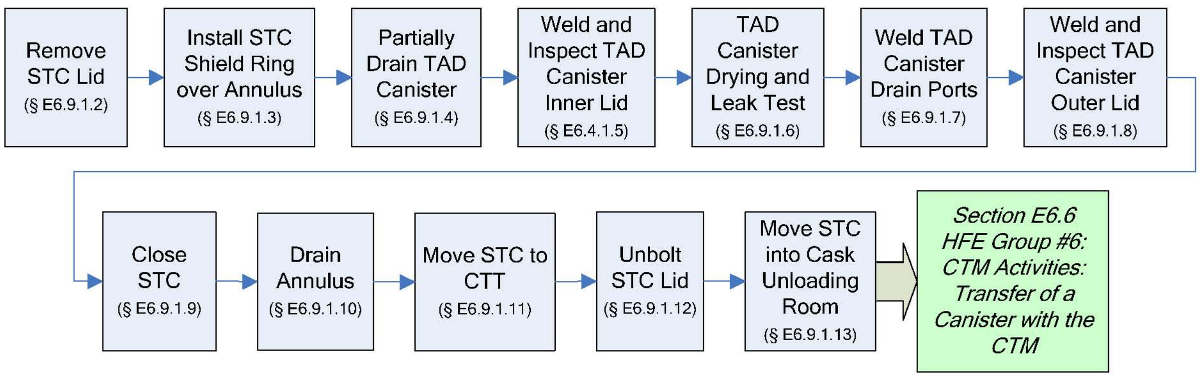
E6.8.3 Detailed Analysis

There are no HFEs in this group that require detailed analysis; the preliminary values in the facility model do not result in any Category 1 or Category 2 event sequences that fail to comply with the 10 CFR 63.111 performance objectives; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.9 ANALYSIS OF HUMAN FAILURE EVENT GROUP #9: TAD CANISTER ASSEMBLY AND CLOSURE

HFE group #9 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering TAD canister closure and movement into the Cask Unloading Room. The operations covered in this HFE group are shown in Figure E6.9-1. This operation begins with the STC/TAD canister stationed in the TAD canister closure platform with the STC lid bolted on. TAD canister closure operations include the drying and welding of the TAD canister, the transfer of a TAD canister/STC unit to a CTT, and the movement of the loaded CTT to the CTM Unloading Room.



NOTE: § = section; CTM = canister transfer machine; CTT = cask transfer trolley; HFE = human failure event; STC = shielded transfer cask; TAD = transportation, aging, and disposal.

Source: Original

Figure E6.9-1. Activities Associated with HFE Group #9

E6.9.1 Base Case Scenario

E6.9.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #9 activities.

1. The STC/TAD canister is sitting in the welding station in the Cask Preparation Area; the TAD canister lid is not welded, but the STC lid is bolted down.

2. The STC has been thoroughly washed down. The radiation protection worker has ensured that there is not excessive radiation due to contamination from the STC.

3. The CTT is an air-pallet apparatus that is guided by two removable rails. The CTT also has end stops to aid in final positioning. A safe load path is marked for the CTT operations, and there are at least three crew members involved in its movement when loaded. The CTT is normally deflated, with control pendant stowed, during preparation activities. The empty CTT is staged underneath the cask preparation platform.

4. The TAD canister closure activities are performed on an elevated platform approximately 28 by 32 ft. Hinged platform sections open to allow the STC to enter the platform area. All equipment and workstations are provided on the work platform.

5. The cask handling crane (200-ton) is in the Cask Preparation Area, and has the following safety features:

   A. Upper limits—there are two upper limit marks: the initial is an indicator, and the final (which is set higher than the upper limit indicator) cuts off the power to the hoist. There is no bypass for the final limit interlock.

   B. There are end-of- travel interlocks on the trolley and bridge.

   C. There are speed limiters built into the motors.

   D. There is a weight interlock that cuts off power to the hoist when the crane capacity is exceeded.

   E. There is a motor drive temperature interlock that cuts off power to the hoist when the temperature is too high. An indicator comes on before this temperature is reached.

   F. There is an indicator to signal the operators that the cask handling yoke is fully engaged, and an interlock (yoke engagement) that prevents the crane from moving unless and the yoke is either fully engaged or disengaged.

Crane operations in this step are not part of a specific procedure outlined in the YMP documentation, but rather reflect critical lift crane operations that are standard in the nuclear industry.

The following personnel are involved in this set of operations:

- Crane operator
- Signaling crew member
- Verification crew member
- Crew members (two)
- Radiation protection worker
- Supervisor
- Quality control
- Level 2 and 3 NDE personnel
- Welding operator
- CTT operator.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel. Personnel in this operation wear the appropriate PPE.

E6.9.1.2 Removal of STC Lid

E6.9.1.2.1 Partially Drain TAD Canister STC

The crew connects a hose to the STC drain port (quick disconnect) and allows the annulus between the STC and TAD canister to partially drain into the pool. The cask is drained to just below the STC lid to prevent undue contamination when opening the cask lid.

E6.9.1.2.2 Removal of STC Lid Bolts

Once the STC is in place at the welding station, the crew uses common tools to remove the STC lid bolts. The removed bolts are counted and verified on a checklist.

E6.9.1.2.3 Removal of STC Lid and Placement in the Laydown Area

The jib crane is used with the lid lifting grapple to remove the STC lid. The STC lid is placed in the laydown area according to the following steps:

Crane Alignment to Cask—The crane operator lowers the jib crane into position over the STC. The operator is positioned on the platform in view of the crew members on either side of the cask. There is a signaling crew member next to the crane who uses hand signals to guide the crane operator (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the crane checking alignment of the crane. The verification crew member can only signal to stop the crane. Once positioned, one of the crew members connects the crane hoist to the cask lid using a grapple.

Vertical Lifting of Lid—Upon signal from the signaling crew member that all is well, the crane operator begins to raise the cask lid. Once the lid is raised (i.e., is hanging free), the crane operator clears the cask and then lowers the lid to the proper movement height based on visual inspection and confirmation by the signaling crew member via hand signals. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path. Throughout this operation, the crew is standing several feet away from the platform opening.

Lid Movement to Staging Area—Using the jib crane, the crane operator positions the lid over the lid stand in the laydown area. To do this, the crane operator follows the indicated safe load path marked on the floor, based on visual cues and confirmatory hand signals from the signaling crew member. The crane operator then sets the lid down and disengages the grapple.

Once the lid is removed, a crew member wipes down the inside of the lid and removes the bladder seal with a long-reach tool.

E6.9.1.3 Installation of STC Shield Ring

The crew uses the jib crane to install a STC shield ring over the annulus.

The crane operator retrieves the STC shield ring from the staging area with the jib crane and lowers the crane into position over the STC. The operator is positioned on the platform in view of the crew members on either side of the cask. There is a signaling crew member next to the crane who uses hand signals to guide the crane operator (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the crane checking the alignment. The verification crew member can only signal to stop the crane. Once positioned, the crane operator lowers the shield ring into place and disengages the grapple.

E6.9.1.4 Partially Drain TAD Canister

The crew attaches a hose to the shield plug siphon port (quick disconnect). The other side of the hose leads to the pool; there is also be a pump connected to the hose to create a vacuum. Once the hose is connected, the crew member turns on the pump and watches the water level in STC. Once the water level reaches just below the TAD canister lid, but before the fuel is exposed, the crew member stops the pump and disconnects the hose.

E6.9.1.5 Welding and Inspection of TAD Canister Inner Lid

E6.9.1.5.1 Movement of TAD Canister Welding Machine to the TAD Canister and Positioning the TAD Canister Welding Machine on the TAD Canister Lid

The jib crane is used to lift the TAD canister welding machine and move it to the TAD canister. This operation is done from the platform. The TAD canister welding machine is set up by personnel using common tools. The welding machine's weight is sufficient to maintain the machine in place, and the welding machine does not need to be bolted down.

Retrieval of the TAD Canister Welding Machine—The crane operator lowers the jib crane with the hook into position over the TAD canister welding machine in the staging area, engages the hook, and lifts the TAD canister welding machine to the proper height for movement based on visual inspection and confirmation by the signaling crew member via hand signals. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of the TAD Canister Welding Machine to TAD Canister—Using the jib crane, the crane operator positions the TAD canister welding machine over the TAD canister in the welding area. The operator follows the indicated safe load path marked on the floor based on visual inspection, and confirmation by the signaling crew member via hand signals. A verification crew member, located opposite the signaling crew member, can signal the crane operator to stop at anytime. The crane operator can roughly align the TAD canister welding machine over the TAD canister, but final alignment is directed by the signaling crew member.

Lowering the TAD Canister Welding Machine—When the TAD canister welding machine is properly positioned over the TAD canister, the signaling crew member signals the crane operator that it is okay to lower the TAD canister welding machine into place. The crane operator proceeds to lower the TAD canister welding machine at or below the maximum allowable speed. Once the TAD canister welding machine is securely in place, the crew member disengages the hook, and the crane operator lifts the crane to its maximum height in preparation for the next operation.

E6.9.1.5.2 TAD Canister Inner Lid Weld and Inspection

The TAD canister inner lid is welded in place using the TAD canister welding machine. All TAD canister welds are stainless steel (spool fed).

The weld machine is semiautomatic and, once set up, makes automatic weld passes around the periphery of the lid while being operated from a remote location.

The welding operator performs visual and ultrasonic testing hand tool inspections of the inner lid The weld is verified and signed off by Level 2 or Level 3 NDE personnel.

E6.9.1.6 Drain TAD Canister Fully, Vacuum Dry, Helium Fill and Leak Test TAD Canister Weld

The crew installs a drying and inerting system on the vent and siphon ports of the inner lid to drain and dry the interior of the TAD canister using pressurized helium. The canister is then backfilled with helium gas. There is a moisture indicator associated with the helium drying system. Once dry and inerted, the weld is leak tested and the drying and inerting system hose is disconnected. This process takes place over several shifts (36 hours or more).

E6.9.1.7 Weld TAD Canister Drain Ports

The TAD canister drain ports are welded in place using the TAD canister welding machine. All TAD canister welds are stainless steel (spool fed).

The welding machine is semiautomatic and, once set up, makes automatic weld passes around the periphery of the port while operated from a remote location. The welding machine does not need to be repositioned in order to weld the drain ports.

E6.9.1.8 Welding and Inspection of TAD Canister Outer Lid

E6.9.1.8.1 Removal of TAD Canister Welding Machine from the TAD Canister

The jib crane is used to remove the TAD canister welding machine from the TAD canister and stage it on the welding machine stand.

Removal of TAD Canister Welding Machine—The crane operator lowers the jib crane into position over the welding machine and engages the hook. Once engaged properly, the crane operator lifts the welding machine and clears the cask, then lowers the machine to the proper height for movement based on visual inspection and confirmation by the signaling crew member via hand signals. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of TAD Canister Welding Machine to Stand—The crane operator moves the jib crane to the welding machine stand, following the safe load path indicated on the floor. The crane operator places the welding machine on the stand and disengages the hook.

E6.9.1.8.2 Placement of Outer Lid on TAD Canister

The jib crane is used to lift the outer lid and move it to the TAD canister. This operation is done from the platform.

Retrieval of the TAD Canister Outer Lid—In the staging area, the crane operator lowers the jib crane with the hook into position over the TAD canister outer lid, engages the hook, and lifts the outer lid to proper height for movement based on visual inspection and confirmation via hand signals by the signaling crew member. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of the TAD Canister Outer Lid to TAD Canister—Using the jib crane, the crane operator positions the TAD canister outer lid over the TAD canister in the welding area. The operator follows the indicated safe load path marked on the floor based on visual inspection and confirmation via hand signals by the signaling crew member. There is a verification crew member opposite the signaling crew member that can signal the crane operator to stop at anytime. The crane operator can roughly align the TAD canister outer lid over the TAD canister, but final alignment is directed by the signaling crew member.

Lowering the TAD Canister Outer Lid—When properly positioned over the TAD canister, the signaling crew member signals the crane operator that it is okay to lower the TAD canister outer lid into place. The crane operator proceeds to lower the TAD canister outer lid at or below the maximum allowable speed. Once the TAD canister outer lid is securely in place, the crew member disengages the hook, and the crane operator lifts the crane to its maximum height in preparation for the next operation.

E6.9.1.8.3 Movement of TAD Canister Welding Machine to the TAD Canister and Positioning the TAD Canister Welding Machine on the TAD Canister Lid

The jib crane is used to place the TAD canister welding machine on the TAD canister lid. The TAD canister welding machine is set up by personnel using common tools. The outer lid has a flat lifting feature on its top with which the weld machine must interface. The TAD canister welding machine is positioned on top of the outer lid's 6-in.-high lifting fixture to perform the closure weld on the outer lid. The welder has at least three pawls that engage the inside of the lifting feature to anchor the welding machine to the TAD canister.

Retrieval of the TAD Canister Welding Machine—In the staging area, the crane operator lowers the jib crane with the hook into position over the TAD canister welding machine, engages the hook, and lifts the TAD canister welding machine to the proper height for movement based on visual inspection and confirmation via hand signals by the signaling crew member. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of the TAD Canister Welding Machine to TAD Canister—Using the jib crane, the crane operator positions the TAD canister welding machine over the TAD canister in the welding area. The operator follows the indicated safe load path marked on the floor based on visual inspection and confirmation by the signaling crew member via hand signals. A verification crew member, opposite the signaling crew member, can signal the crane operator to stop at anytime.

The crane operator can roughly align the TAD canister welding machine over the TAD canister, but final alignment is directed by the signaling crew member.

Lowering the TAD Canister Welding Machine—When properly positioned over the TAD canister, the signaling crew member signals the crane operator that it is okay to lower the TAD canister welding machine into place. The crane operator proceeds to lower the TAD canister welding machine at or below the maximum allowable speed. Once the TAD canister welding machine is securely in place on the lifting feature of the outer lid, the crew member engages the pawls that connect the welding machine to the outer lid's lifting fixture. The crew member then disengages the crane hook and signals the crane operator to lift the crane to its maximum height in preparation for the next operation.

E6.9.1.8.4 TAD Canister Outer Lid Welding and Inspection

The TAD canister outer lid is welded in place using the TAD canister welding machine. All TAD canister welds are stainless steel (spool fed).

The weld machine is semiautomatic and, once set up, makes automatic weld passes around the periphery of the lid while being operated from a remote location.

The welding operator performs visual and ultrasonic testing inspections of the outer lid weld using hand tools. The weld is verified and signed off by Level 2 or Level 3 NDE personnel.

E6.9.1.8.5 Removal of TAD Canister Welding Machine from the TAD Canister

The jib crane is used to remove the TAD canister welding machine from the TAD canister and stage it on the welding machine stand.

Removal of TAD Canister Welding Machine—The crane operator lowers the jib crane into position over the welding machine and a crew member engages the hook. Once engaged properly, the crew member disengages the pawls from the outer lid and then signals the crane operator to lift the welding machine. The crane operator lifts the machine and clears the cask, then lowers the machine to the proper height for movement based this on visual inspection and confirmation by the signaling crew member via hand signals. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of TAD Canister Welding Machine to Stand—The crane operator moves the jib crane to the welding machine stand, following the safe loading path indicated on the floor. The crane operator places the welding machine on the stand and disengages the hook.

E6.9.1.9 Closure of STC

E6.9.1.9.1 Removal of STC Shield Ring

The crane operator uses the jib crane and standard rigging to remove the STC shield ring from the STC. This operation is done from the cask preparation platform with the aid of two crew members. The crane operator moves the crane to the STC and the crew members attach the rigging to the shield ring. The crew members then step several feet away from the cask and the crane operator lifts the shield ring, ensures that it is steady, and moves the shield ring to its staging area.

E6.9.1.9.2 Installation of STC Lid

The jib crane and lid lifting grapple are used to lift the STC lid and place it onto the STC. This operation is done on the cask preparation platform. In preparation of this step, the lid lifting grapple is attached to the jib crane, and there is a lid lifting fixture attached to the STC lid.

The crane operator retrieves the STC lid from the staging area with the jib crane and lowers crane into position over the STC. The operator is positioned on the platform in view of the crew members on either side of the cask. There is a signaling crew member next to the crane that uses hand signals to guide the crane operator (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the crane checking alignment of the crane. The verification crew member can only signal to stop the crane. Once positioned, the crane operator lowers the lid into place and disengages the grapple.

E6.9.1.9.3 Install STC Lid Bolts

The STC lid is bolted (using at least four bolts) to the STC by personnel using common tools. This step is verified on a checklist.

E6.9.1.10 Draining the Annulus between the STC and TAD Canister

The crew attaches a hose to the shield plug siphon port (quick disconnect), while the other side of the hose leads to the pool. There is a pump connected to the hose to create a vacuum. Once the hose is connected, the crew member turns on the pump and waits until the annulus is fully drained (in the pool a crew member can see bubbles coming from the hose). The crew member then stops the pump and disconnects the hose. The STC drain port is then closed by a crew member using common tools.

E6.9.1.11 Movement of the STC to CTT

The STC is moved to the Cask Preparation Area using the cask handling crane with the cask handling yoke. In preparation for this step, the cask handling yoke is attached to the cask handling crane. The CTT is deflated under the preparation platform.

Movement of Crane to STC—The operator positions the crane over the STC. The operator follows the indicated safe load path marked on the floor based on visual inspection and hand signal confirmation from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Crane Alignment with Cask—The crane operator lowers the crane into position so that the yoke arms are lined up with the trunnions. The operator is positioned on the floor in view of the crew members on either side of the cask. There is a signaling crew member next to the cask who uses hand signals to guide the crane operator (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the cask checking alignment of the second trunnion. The verification crew member can only signal the crane operator to stop.

Engagement of Yoke Arms on Trunnions—Once the yoke is aligned, the signaling crew member signals the operator to close the yoke arms. The crew members check to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). The crane operator can see by an indicator on the controller that the arms are fully engaged on both sides. The signaling crew member signals the operator to raise the crane a slight amount to put pressure on the arms. Again, the crane operator can see on the controller that the crane is bearing weight. Once the cask is lifted slightly, both crew members verify that the yoke is level. If the arms do not engage on the initial attempt either crew member signals the operator to stop, and the crane operator sets the cask down, and opens the yoke arms to disengage. The signaling crew member then directs movement of the crane (again with hand signals) to compensate, and signals the operator to close the yoke arms.

Movement of Cask to CTT—The crane operator raises the cask to the proper height for movement. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path. The operator confirms the height visually and gets confirmation from the signaling crew member before beginning movement to the Cask Preparation Area. The crane operator follows the indicated safe load path marked on the floor based on visual inspection and confirmation from the signaling crew member. There is a verification crew member that is on the opposite side of the cask as the signaling crew member. With the help of both crew members, the crane operator aligns the cask to the CTT and then lowers the cask in the CTT.

Secure Cask to CTT—Prior to disengaging the yoke from the cask, the crew members use common tools to secure the cask to the CTT. The crane operator then disengages the yoke, lifts the crane to the proper height for movement and moves the yoke to the yoke stand.

E6.9.1.12 Unbolting STC Lid

Once secure in the CTT, the crew lowers the preparation platform and unbolts the STC lid using common tools and the preparation platform.

E6.9.1.13 Movement of STC into Cask Unloading Room

Using the CTT, the CTT operator moves the STC to the Cask Unloading Room and positions the cask under the cask port. To do this, the CTT operator inflates the CTT, moves the CTT to the Cask Unloading Room door, opens the shield door, moves the CTT through the door and positions it under the cask port, deflates the CTT and stores the pendant, disconnects the air hose, and closes the shield door. There are physical stop points in the Cask Unloading Room which the CTT must bump up against to ensure proper alignment.

E6.9.2 HFE Descriptions and Preliminary Analysis

This section defines and screens the HFEs that are identified for the base case scenario, that can affect the probability of initiating events occurring, and that could lead to undesired consequences. Descriptions and preliminary analysis for the HFEs of concern during TAD canister closure and movement to the Cask Unloading Room are summarized in Table E6.9-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

Table E6.9-1. HFE Group #9 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpTCImpact10-HFI-NOD	*Operator Causes an Impact between a Cask and an SSC during TAD Canister Closure*: While performing crane operations, the operator can impact the cask in the following ways: • Impacting the cask while moving an object with the crane • Impacting the cask with the crane hook	25	6E−03	This HFE is very similar to the standard impact due to crane operations (050-OpTCImpact01-HFI-NOD; 0.003) in regards to the operations involved and failure modes. The justification for those failures is as follows: the preliminary value was chosen based on the determination that this failure is "highly unlikely" (one in a thousand or 0.001) and was adjusted because there are several ways for an impact to occur (×3). However, for this operation, there is a cask lift and (comparatively) several more equipment lifts that may be done over multiple shifts; therefore this HEP was adjusted by an additional factor (×2).
050-OpTCImpact01-HFI-NOD	*Operator Causes an Impact between a Cask and an SSC during TAD Movement to CTT*: While moving the TAD to the CTT from the TAD closure station, the crane operator can cause the cask to impact an SSC in the following ways: • Move crane in wrong direction • Move crane with hoist too low • Move load out of safe load path • Object is left in the safe load path.	28	3E−03	This HFE is identical to the standard impact due to crane operations (i.e., impact during upending and removal from conveyance, HFE Group #2, 050-OpTCImpact01-HFI-NOD; 0.003) in regards to the operations involved and failure modes. The justification for those failures is as follows: the preliminary value was chosen based on the determination that this failure is "highly unlikely" (one in a thousand or 0.001) and was adjusted because there are several ways for an impact to occur (×3).
050-OpSTCShield1-HFI-COD	*Operator Causes a Direct Exposure Due to Failure to Properly Install the STC Shield Ring*: In this step, the TAD canister is dried and the TAD canister lids are welded on. The crew can get a direct exposure if the crane operator improperly places the STC shield ring on the STC during TAD canister closure activities.	29	1E−02	In this step, the STC shield ring is placed over the annulus so the crew can perform the welding operations. During this operation the crane operations are simple, the ring is attached via standard rigging to the crane, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a daily basis. There are no interlocks to prevent this error. To add to the complexity of this task, the actual alignment is done at a distance with the aid of a camera. If the shield ring is misaligned, it can be seen from the platform. This operation was given the default value for an "unlikely" event. This operation is nearly identical to operator fails to properly install DPC shield ring (050-OpDPCShield1-HFI-NOW; Section E6.7, HFE Group #7), and the preliminary values reflect this.
050-TadDry-Fail	*Operator Leaves Water in the TAD Canister*: If the operator prematurely terminates TAD canister drying or otherwise fails to ensure the TAD canister is fully dry before closure, this can result in damage to the canister or fuel assemblies.	26	N/A	If the operator prematurely terminates the TAD canister drying or otherwise fails to ensure the TAD canister is fully dry before closure, there can be resulting damage to the canister or fuel assemblies. This failure event was screened out by the WHF analysts and is not part of this HRA; Sections 6.0 of the main report provides the screening justification.
050-WeldDetect-Fail	*Operator Causes Defective Weld or Fails to Detect a Bad Weld*: The welding system is highly automated, with few opportunities for humans to intervene. The weld check system is highly automated using an ultrasonic tester, but at least one human is supposed to visually inspect each weld and sign off on it. If the TAD canister inner and outer lids both have a bad weld that is cracked all the way through, then a radiation release can occur.	27	N/A	If the TAD canister inner and outer lids both have a bad weld that is cracked all the way through, then a radiation release can occur. This failure event was screened out by the WHF analysts and is not part of this HRA; Sections 6.0 of the main report provides the screening justification.
050-OpTipover001-HFI-NOD	*Operator Causes CTT to Tip Over while Moving into the Preparation Station*: During this operation, the CTT is moved from the TAD canister closure station to the preparation station and then to the Cask Unloading Room. Several crane operations are carried out during TAD canister closure both at the closure station and at the preparation station. If the crane rigging is attached to the cask or CTT (either accidentally or purposefully) and the crane or CTT moves, the cask can potentially tip over. The following are contributors to this HFE: • Crane hook, grapple or rigging catches conveyance/cask • Horizontal movement of the crane with the hook lowered and attached to cask • Crane travels in wrong direction.	28	1E−04	In this step the CTT is moved from the Cask Preparation Area to the preparation station for lid bolt removal, and then to the Cask Unloading Room where it is positioned under the cask port. This HFE was assigned the same preliminary value as other cask tipover events (050-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because the operations and failure modes are identical; the CTT can catch improperly stowed crane rigging in the Cask Preparation Area and the crane or CTT can continue moving and result in a tipover. The following is the rationale behind this preliminary value: the dominant contributor is the crane hook catching the cask. While it may be unlikely (0.01) that a stray hook or grapple might be hanging from the crane, it would still need to catch on the cask securely enough to pull it over (0.1), and then the cask tipping would have to go unnoticed by all three observers. This is done with direct observation, and a tipover is a slow process; therefore, the value was adjusted by a further 0.1.

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Table E6.9-1. HFE Group #9 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpCTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of Auxiliary Vehicle with STC*: During STC unbolting at the preparation station, the STC is loaded and parked under the preparation platform. During this time, an operator can cause an auxiliary vehicle to collide with the STC. The TAD canister closure station design precludes an auxiliary vehicle from colliding with the TAD canister stationed in the closure station.	25	3E−03	In this step the CTT is loaded and parked under the cask preparation platform. The TAD canister cannot be impacted in the TAD canister closure station because it is protected by the platform itself. The speed of auxiliary vehicles is slow, the CTT is very visible, and procedural controls are expected to limit the number of other vehicles in the Cask Preparation Area during cask operations. This HEP was assigned the same preliminary probability as a railcar collision HFE (050-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) because the dominant mechanism of both failures is collision with an auxiliary vehicle. In this case, the preliminary value is conservative because the CTT is staged under the platform and the railcar collision HFE has additional failure modes associated with movement of the SPM that are not applicable here. This failure is identical for the preparation activities in a CTT (050-OpCTCollide1-HFI-NOD; Section E6.3, HFE Group #3 and Section E6.4, HFE Group #4) and has the following justification: the preliminary value was chosen based on the determination that this failure is "highly unlikely" (one in a thousand or 0.001), was adjusted because there are several ways for a collision to occur, and there are potentially multiple other vehicles (forklifts) that can collide into the conveyance (×3).
050-OpFLCollide1-HFI-NOD	*Operator Causes High-Speed Collision of Auxiliary Vehicle with STC*: During STC unbolting at the preparation station, the STC is loaded and parked under the preparation platform. During this time, an operator can cause an auxiliary vehicle to collide with the STC. If the collision is due to the auxiliary vehicle speed governor malfunctioning, then this is a high-speed collision.	25	1.0	An auxiliary vehicle (i.e., forklift) can over speed, resulting in collision with the CTT while the CTT is parked under the preparation platform or in transit to or from the platform. In order to accomplish this, the speed governor of the auxiliary vehicle must fail. The CTT itself is limited by design from over speeding. To be conservative, unsafe actions that require an equipment failure to cause an initiating event are assigned an HEP of 1.0.
050-OpCTCollide2-HFI-NOD	*Operator Causes Low-Speed Collision of CTT during Transfer from the Preparation Station to the Unloading Room*: Once the TAD canister is closed and the STC bolts are removed, an operator inflates the CTT and moves the cask from the Cask Preparation Area to the Cask Unloading Room. The operator can cause the CTT to collide with the preparation platform structure or other SSCs during this transfer. The CTT is designed such that it physically cannot over speed; therefore, all CTT collisions are below the designed speed.	10	1E−03	In this step the CTT is moved from the Cask Preparation Area to the preparation station for lid bolt removal and then to the Transfer Room where it is positioned under the cask port. This HFE was assigned the same preliminary value as other collisions during CTT movement (050-OpCTCollide2-HFI-NOD; Section E6.5, HFE Group #5) because the operations, opportunities for collision, and failure modes are very similar. This operation is simple, is straightforward, is expected to occur very regularly (daily), and was assigned the default probability of a "highly unlikely" occurrence (0.001). It was considered reasonable and consistent that the preliminary value assigned for this HFE be less likely than a railcar or auxiliary vehicle collision because of the CTT guide rail, number of observers, and short travel distance.
050-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance*: Once the TAD canister is closed and the STC lid is unbolted, the TAD canister is moved from the Cask Preparation Area to the Cask Unloading Room. There is a shield door between the Cask Preparation Area and the Cask Unloading Room. The operator can impact the cask by inadvertently closing the shield door on the CTT/STC as the CTT passes through the door.	12	1.0	The CTT passes through a shield door as it moves from the preparation station into the Cask Unloading Room. During this transfer, the operator can cause the CTT to collide into the shield door or can close the shield door on the CTT. Section E6.0.2.3.3 provides a justification of this preliminary value.

NOTE: CTT = cask transfer trolley; DPC = dual-purpose canister; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; HRA = human reliability analysis; N/A = not applicable; SSC = structure, system, or component; SSCs = structures, systems, and components; STC = shielded transfer cask; TAD = transportation, aging, and disposal; WHF = Wet Handling Facility.

Source: Original

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E6.9.3 Detailed Analysis

After the preliminary screening analysis and initial quantification are completed, those HFEs that appear in dominant cut sets for event sequences that do not comply with the 10 CFR 63.111 performance objectives are subjected to a detailed analysis. The overall framework for the HRA is based upon the process guidance provided in ATHEANA (Ref. E8.1.22). Consistent with that framework, the following four steps from the methodology described in Section E3.2 provide the structure for the detailed analysis portion of the HRA:

Step 5: Identify Potential Vulnerabilities

Prior to defining specific scenarios that can lead to the HFEs of interest (Step 6), information is collected to define the context in which the failures are most likely to occur. In particular, analysts search for potential vulnerabilities in the operators' knowledge and information base for the initiating event or base case scenario(s) under study that might result in HFEs or unsafe actions. This information collection step discussed in Section E6.9.3.2.

Step 6: Search for HFE Scenarios (Scenarios of Concern)

An HFE scenario is a specific progression of actions with a specific context that leads to the failure of concern; each HFE is made up of one or more HFE scenarios. In this step, documented in Sections E6.9.3.3 and E6.9.3.4, the analyst identifies deviations from the base case scenario that are likely to result in risk-significant unsafe action(s). These unsafe actions make up an HFE scenario. In serious accidents, these HFE scenarios are usually combinations of various types of unexpected conditions.

Step 7: Quantify Probabilities of HFEs

Detailed HRA quantification methods are selected as appropriate for the characteristics of each HFE and are applied as explained in Section E6.9.3.4. Four quantification methods are utilized in this quantification:

- CREAM (Ref. E8.1.18)
- HEART (Ref. E8.1.28)/NARA (Ref. E8.1.11)
- THERP (Ref. E8.1.26)
- ATHEANA expert judgment (Ref. E8.1.22).

There is no implication of preference in the order of listing these methods. They are jointly referred to as the "preferred methods" and are applied either individually or in combination as best suited for the unsafe action quantified. The ATHEANA (Ref. E8.1.22) expert judgment method (as opposed to the overall ATHEANA (Ref. E8.1.22)) methodology that forms the framework and steps for the performance of this HRA) is used when the other methods are deemed to be inappropriate to the unsafe action, as is often the case for cognitive EOCs.

Appendix E.IV of this analysis explains why these specific methods were selected for quantification and gives some background on when a given method is applicable based on the focus and characteristic of the method.

All judgments used in the quantification effort are determined by the HRA team and are based on their own experience, augmented by facility-specific information and the experience of subject matter experts, as discussed in Section E4. If consensus can be reached by the HRA team on an HEP for an unsafe action, that value is used as the mean. If consensus cannot be reached, the highest opinion is used as the mean.

Step 8: Incorporate HFEs into the PCSA

After HFEs are identified, defined, and quantified, they must be incorporated into the PCSA. The summary table of HFEs by group that lists the final HEP by basic event name provides the link between the HRA and the rest of the PCSA. This table can be found in Section E6.9.4.

E6.9.3.1 HFEs Requiring Detailed Analysis

The detailed analysis methodology, Sections E3.2.5 through E3.2.9, states that HFEs of concern are identified for detailed quantification through the preliminary analysis (Section E3.2.4). An initial quantification of the WHF PCSA model determined that there was one HFE in this group whose preliminary value was too high to demonstrate compliance with the performance objectives stated in 10 CFR 63.111. This HFE is presented in Table E6.9-2.

Table E6.9-2. Group #9 HFE Requiring Detailed Analysis

HFE	Description	Preliminary Value
050-OpSTCShield1-HFI-COD	Operator causes direct exposure due to failure to properly install STC shield ring	1E−02

NOTE: HFE = human failure event; STC = shielded transfer cask.

Source: Original

E6.9.3.2 Assessment of Potential Vulnerabilities (Step 5)

For those HFEs requiring detailed analysis, the first step in the approach to conducting a detailed quantification is to identify and characterize factors that could create potential vulnerabilities in the crew's ability to respond to the scenarios of interest and might result in HFEs or unsafe actions. In this sense, the "vulnerabilities" are the context and factors that influence human performance and constitute the characteristics, conditions, rules, and tendencies that pertain to all the scenarios analyzed in detail.

These vulnerabilities are identified through activities including but not limited to the following:

1. The facility familiarization and information collection process discussed in Section E4.1, such as the review of design drawings and concept of operations documents.

2. Discussions with subject matter experts from a wide range of areas, as described in Section E4.2.

3. Insights gained during the performance of the other PCSA tasks (e.g., initiating events analysis, systems analysis, and event sequence analysis).

The vulnerabilities discussed in this section pertain only to those aspects of the preparation operation that relate to potential human failure scenarios relevant to the HFE listed in Table E6.9.2. Other vulnerabilities exist that would be relevant to other potential HFEs that can occur during the preparation operation, but these have no bearing on this analysis.

E6.9.3.2.1 Operating Team Characteristics

Crane Operator—The crane operator has received standard training for crane operations and observed operations prior to being allowed to operate the crane on a dry run. Based on evaluation of the crane operator's proficiency in a dry run, the crane operator is signed off to operate the crane. On initial operations, the crane operator is observed until signed off for solo operation. A single operator is assigned to the crane operation.

Signaling Crew Member—During the shield ring movement to the TAD canister/STC, the signaling crew member provides hand signals to the crane operator to direct the movement of the crane.

Verification Crew Member—The verification crew member is stationed in view of the TAD canister/STC and shield ring and covers the areas that the signaling crew member cannot see. The verification crew member gives hand signals to the signaling crew member if there are any problems with the alignment of the shield ring.

Radiation Protection Worker—The radiation protection worker is a fully certified health physics technician, whose job is to monitor radiation from the cask during cask handling operations. The radiation protection worker is responsible for stopping operations if high radiation levels are detected or if there is a situation that would lead to direct exposure.

E6.9.3.2.2 Operation and Design Characteristics

Control Panel—The control panel consists of a standard jib control panel for movement of the crane. Controls are provided for both coarse and fine motion. A camera view is provided to augment the operator's direct view from a distance. The crane operator and crew members are located on the platform, several feet away from the cask.

Interlocks/Alarms—There are no interlocks or alarms that control this task. A radiation protection worker takes a manual reading of radiation levels and prevents operations if high radiation is detected.

Verbal Communication—Verbal communication between crew members and the crane operator is ineffective. A significant amount of machine noise is present, so hand signals are the only practical means of communication.

E6.9.3.2.3 Formal Rules and Procedures

Procedures—Procedures exist for these operations; however, there are no written, formal procedures that the crew has in front of them during cask preparation. Operators and crew members are trained in the operations, and their proficiency is attested to by the training staff. They perform the operations as a skill.

Formal Rule—This operation involves potential radiation exposure, so a formal rule exists that the radiation protection worker must measure the radiation in the area of the TAD canister where the workers are located. Radiation protection workers do not have to formally sign off on the measurement of the radiation level; however, they need to inform the crane operator and crew members that it is safe to continue working in the area.

E6.9.3.2.4 Operator Tendencies and Informal Rules

Crane Operator Dependency on Crew Members—The view from the control panel and through the camera are reasonable for rough placement of the shield ring, but final alignment is directed through hand signals from crew members.

Crew Member Deference to the Crane Operator—The crane operator is essentially the foreman of the team, and is seen by the crew members as being in a more skilled position than them. The crew tends to defer to the crane operator's judgment and have some level of reluctance to question the operator's directions.

E6.9.3.2.5 Operator Expectations

Shield ring installation is a simple task ancillary to the main task of draining the TAD canister. The operator and crew expect the operation to go smoothly.

E6.9.3.3 HFE Scenarios and Expected Human Failures (Step 6)

Given that the vulnerabilities that provide the operational environment and features that could influence human performance have been specified, then the HFE scenarios within this environment are identified. An HFE scenario is a specific progression of actions during normal operations (with a specific context) that lead to the failure of concern; each HFE is made up of one or more HFE scenarios. In accordance with the methodology, each scenario integrates the unsafe actions with the relevant equipment failures so as to provide the complete context for the understanding and quantification of the HFE.

The HAZOP evaluation is instrumental in initially scoping out the HFE scenarios, but the HFEs are then refined through discussions with subject matter experts from a wide range of areas, as described in Section E4.2.

Table E6.9-3 summarizes all of the HFE scenarios developed for the HFEs in this group.

Table E6.9-3. HFE Scenarios and Expected Human Failures for HFE Group #9

HFE	HFE Scenarios
050-OpSTCShield1-HFI-COD *Operator Causes Direct Exposure Due to Improper Installation of STC Shield Ring*	HFE Scenario 1(a): (1) Crane operator fails to install shield ring; (2) Crew members fail to note that shield ring installation has been skipped; (3) Crew members fail to notice that shield ring is not in place prior to approaching TAD canister. HFE Scenario 1(b): (1) Crane operator installs shield improperly; (2) radiation protection worker fails to check radiation levels OR radiation protection worker misreads radiation level OR radiation monitor fails; (3) Crew member fails to note shield ring out of position before approaching TAD canister.

NOTE: HFE = human failure event; STC = shielded transfer cask; TAD = transportation, aging, and disposal.

Source: Original

Since there is one HFE identified for detailed analysis in this group, the scenarios are organized under this HFE category, with the scenarios numbered as 1(a) and 1(b).

Each HFE scenario is in turn characterized by several unsafe actions, numbered sequentially as (1), (2), or (3). The Boolean logic of the HFE scenarios is expressed with an implicit AND connecting the subsequent unsafe actions and OR notation wherever two unsafe action paths are possible, as shown in Table E6.9-3.

The HFE scenarios summarized in Table E6.9-3 are discussed and quantified in the following sections.

E6.9.3.4 Quantitative Analysis (Step 7)

Once the HFE scenarios and the unsafe actions within them are scoped out, it is then possible to review them in detail and apply the appropriate quantification methodology in each case that permits an HEP to be calculated for each HFE. Stated another way, each HFE is quantified through the analysis and combination of the contributing HFE scenarios. Dependencies between the unsafe actions and equipment responses within each scenario and across the scenarios are carefully considered in the quantification process.

This section provides a description of the quantitative analysis performed. This quantitative analysis is structured hierarchically by each HFE category (identified by a basic event name), followed by the HFE scenario, and then followed by the unsafe actions under each scenario as documented in Table E6.9-3.

Prior to the scenario-specific quantification descriptions, a listing is provided of the values used in the quantification that are common across many of the HFE scenarios.

In generating the final HEP values, the use of more than a single significant figure is not justified given the extensive use of judgment required for the quantification of the individual unsafe actions within a given HFE. For this reason, all calculated final HEP values are reduced to one significant figure. When doing this, the value is always rounded upwards to the next highest single significant figure.

E6.9.3.4.1 Common Values used in the HFE Detailed Quantification

There are no mechanical failures that appear in multiple HFE scenarios.

E6.9.3.4.2 Quantification of HFE Scenarios for 050-OpSTCShield1-HFI-COD: Operator Causes Direct Exposure Due to Failure to Install STC Shield Ring

E6.9.3.4.2.1 HFE Group #9 Scenario 1(a) for 050-OpSTCShield1-HFI-COD

1. Crane operator fails to install shield ring.

2. Crew members fail to realize that the shield ring installation has been skipped.

3. Crew members fail to notice that the shield ring is not in place prior to approaching the TAD canister.

Crane Operator Fails to Install Shield Ring—The crane operator is responsible for ensuring that the shield ring is installed prior to the crew members setting up the TAD canister draining system and partially draining the TAD canister. The crew members assist in this process by handling the rigging and providing hand signals to the crane operator to help in placement of the shield ring. Since this is a radiation protection task, the operator must contact the Health Physics Department and inform them that the operation is about to take place so that a radiation protection worker can check radiation levels after shield placement. The unsafe action in this case is that the crane operator fails to perform this entire step and tells the crew to partially drain the TAD canister. The operator's motivation for doing this could be that the shield ring is viewed as unnecessary for this task, the operator "remembers" already installing it from having done this operation many times before, the operator is anxious to get the job done, or the operator is distracted by other activities and simply forgets.

The jib crane operator is required to install the shield ring prior to the crew members partially draining the TAD canister. The unsafe action in this case is that the jib crane operator skips this entire part of the process and tells the crew members to drain the TAD canister. This can be represented by CREAM CFF E5, adjusted for the following CPCs with a value not equal to 1.0, as follows:

- CFF E5: Action missed, not performed (omission). The baseline HEP is 0.03.

- CPC "Available Time": The general level of time pressure for the overall process of draining the TAD canister is very low. There is no particular impetus for getting the task done that would potentially drive the operator to skipping this task. The CPC weighting factor for an execution task with adequate time is 0.5.

- CPC "Adequacy of Training and Preparation": This routine task is well trained and practiced and performed quite frequently. The CPC weighting factor for an execution task with adequate training and high experience is 0.8.

Note that in skipping this entire task, it is deemed that the operator also fails to inform the Health Physics Department that they are needed to perform monitoring after the shield ring is installed.

Applying these factors yields the following:

Crane operator fails to install shield ring = $0.03 \times 0.5 \times 0.8 = 0.01$

Crew Members Fail to Realize that Shield Ring Installation Has been Skipped—The crew members that drain the TAD canister are an integral part of the overall task process, including the placement of the shield ring. They should be aware that the ring needs to be placed, and should question the crane operator if the crane operator tells them to begin the unbolting task when the crew has not been a part of the placement process. In addition, the crew members should also be expecting to see a radiation protection worker check radiation levels and give them the "all clear" signal to approach the TAD canister. The crew members have a particular motivation to ensure that this is done, since the crew members (not the crane operator) are exposed if the shield ring is not installed. The unsafe action in this case is that they do not question the crane operator when told to begin the draining task. It is expected that their motivation for this unsafe action is most likely to be a reluctance to question the crane operator, who is above them in the operational hierarchy of the facility (i.e., the crane operator is essentially the foreman of the team). The crew member's deference to the crane operator's instruction would come from a belief that the crane operator was in charge and aware of the situation.

Because the crew members that partially drain the TAD canister are the same crew members that assist in the shield ring installation process (i.e., preparing the crane, signaling the operator, etc.), the crew members need to miss this entire task for this event to occur. As a baseline value for this event, the same probability as crane operator fails to install shield ring can be used (0.01). However, the crew members would not be totally independent of the crane operator. The crew members could be distracted, or they could be starting a new shift and be convinced by the crane operator that the TAD canister is ready to be drained (i.e., a bias towards believing that the operator, who would generally be considered above them in the operational hierarchy, must be aware of the status of the operation). On the other hand, the crew members would clearly expect to participate in this task and because it is important to their personal safety (i.e., they are the ones who are depending on the shielding) they are more cognizant of the operational status. Taking all of this into consideration, it is deemed that the level of dependence is low. For low dependence when a baseline HEP is 0.01, the adjusted HEP is taken from THERP Table 20-21, item (2)(a) (Ref. E8.1.26) as follows:

Crew members fail to note that shield ring installation has been skipped = 0.05

Crew Members Fail to Notice that the Shield Ring Is Not in Place Prior to Approaching the TAD Canister—After the crew members are cleared to begin the draining task, they gather the required tools and approach the TAD canister. The crew members would have performed this task many times before, and would have an image in their minds of how everything should look. The ring is a large and rather obvious device that the crew members would have to walk on or over in order to perform the draining. Since they would not be exposed until the TAD canister was partially drained (because the water provides shielding) they could walk up to the TAD canister before noticing the missing shield ring and even start the task (i.e., connect the system) and still not be exposed. The crew members are carrying the tools they need, focusing on the performance of the task, and likely talking to each other about the performance of the task or having a casual conversation (since the work is not particularly difficult or challenging and they are not expecting any complications). The unsafe action results from the crew members not noticing that the configuration of the shield ring is not correct. Most likely, the crew members would have a bias that the operational conditions are in order and it is time to perform the task; the crew does not detect the differences in appearance (i.e., they see what they expect to see). To put this in a more colloquial context, this type of missed observation would be comparable to an individual walking up to their car and failing to notice that the door of the car is open, up to the point of opening the door and getting in.

Although there is no specific check that takes place when the crew goes to partially drain the TAD canister, there is opportunity to notice that the shield ring is not in place. They would have ample opportunity to detect that the shield ring is not in place, since there is no risk of exposure until the TAD canister is partially drained (prior to that, the water would provide adequate shielding). Therefore, the crew would be located at the TAD canister and have a clear view. The crew would have to not notice that the shield ring is not there before they begin draining water. Rather than missing a check, it is more in the nature of failing to notice that something is not correct.

There are no failures in the primary quantification methods that reasonably fit this unsafe action, so it is necessary to provide a value based on expert judgment (ATHEANA). It is clear that some credit needs to be given for this since the crew members perform this task often and should recognize what the configuration should look like when they perform the task, especially given that they would be within a few feet of the TAD canister for several minutes performing preparatory tasks before the drain. However, in opposition to this, the crew begins operations on the TAD canister believing the shield ring is in place and they are focused on the task that they are about to perform. Taking all of this into consideration, the HRA team believes that the failure is unlikely, which corresponds to an HEP of 0.1.

Crew members fail to notice that the shield ring is not in place
prior to approaching the TAD canister = 0.1

HEP Calculation for Scenario 1(a)—The events in the HEP model for Scenario 1(a) are presented in Table E6.9-4.

Table E6.9-4. HEP Model for HFE Group #9 Scenario 1(a) for 050-OpSTCShield1-HFI-COD

Designator	Description	Probability
A	Crane operator fails to install shield ring	0.01
B	Crew members fail to realize that shield ring installation has been skipped	0.05
C	Crew members fail to notice that shield ring is not in place prior to approaching TAD canister	0.1

NOTE: HEP = human error probability; HFE = human failure event; TAD = transportation, aging, and disposal.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C = 0.01 \times 0.05 \times 0.1 = 0.00005 \quad \text{(Eq. E-43)}$$

E6.9.3.4.2.2 HFE Group #9 Scenario 1(b) for 050-OpSTCShield1-HFI-COD

1. Crane operator installs shield improperly.

2. Radiation protection worker fails to check radiation levels OR the radiation protection worker misreads the radiation level OR the radiation monitor fails.

3. Crew member fails to note shield ring is out of position before approaching the TAD canister.

Crane Operator Installs Shield Ring Improperly—The installation process is relatively simple and straightforward. Once the crew members attach the shield ring to the jib crane sling, the operator moves it over the TAD canister. The crew members help the operator to align the shield ring properly over the TAD canister using hand signals. The crew members signal the crane operator throughout the lowering process to ensure proper alignment. Although the operation is simple, the shield ring must have a close fit in order to completely block the annulus between the TAD canister and the STC to prevent radiation from escaping and exposing workers when they approach the TAD canister/STC unit. If the shield ring is not exactly aligned, it could partially jam or hang up at a slight angle that would allow radiation to escape. The unsafe action is that the operator causes the shield ring to partially jam or hang up. Included in this is the implicit condition that the crane operator and crew members do not notice that the shield ring is jammed or hung up as they perform the task.

In this case, the crane operator is performing the shield installation task, but the shield ring is not seated properly. This is a very routine task and is practiced often. Failures can be corrected without consequences since the operator has the opportunity to lift and place the shield ring as many times as necessary until it is properly aligned. This can be represented by NARA GTT A5, adjusted by the following EPCs:

- GTT A5: Completely familiar, well designed, highly practiced, and routine task performed to highest possible standards by highly motivated, highly trained, and experienced personnel, totally aware of implications of failure, with time to correct potential errors. The baseline HEP is 0.0001.

- EPC 11: Poor, ambiguous, or ill-matched system feedback. This EPC addresses the issue that the crane operator views this operation from a distance. The maximum effect is ×4, which applies to a very difficult situation where visibility is poor, and visual and physical access if difficult. It is not believed that this case is this severe, but the full effect is still applied. The APOA is set to 1.0.

Applying the NARA HEP equation yields the following:

$$\text{Crane operator installs shield ring improperly} = 0.0001 \times [(4-1) \times 1 + 1] = 0.0004 \quad \text{(Eq. E-44)}$$

Radiation Protection Worker Fails to Check Radiation Levels—The crane operator contacts the Health Physics Department before initiating the shield ring placement task, and awaits clearance that radiation levels are acceptable before ordering the crew members to unbolt the lift fixture. There are three potential ways that the radiation protection worker could fail to properly determine that the shield ring is not properly in place. First, the radiation protection worker could forget to perform the measurement; however, since the only reason the radiation protection worker was called to the WHF was to perform this task, the radiation protection worker would need to be distracted by something or someone to not perform this measurement. The radiation protection worker has performed this task a number of times in the past, and it is possible that the radiation protection worker could remember performing this task before and get confused and signal the operator that the levels are acceptable, believing that the radiation measurement has been performed. To put this in a more colloquial context, this type of omission would be comparable to an individual leaving their home or office without setting an alarm system. This individual performs this task every time they exit, and it has become second nature, so they cannot believe that they did not do it this time.

In this case, the unsafe action results from the radiation protection worker not checking radiation levels, after being called in specifically to perform this task. This can be represented by CREAM CFF E5, adjusted by the following CPCs with a value other than 1.0.

- CFF E5: Action missed, not performed (omission). The baseline HEP is 0.03.

- CFP “Adequacy of Training/Preparation”: This routine task is well trained, practiced, and performed quite frequently. The CPC for an execution task with adequate training and high experience is 0.8.

- CFP “Available Time”: There is adequate time to perform this task and no significant time pressure. The CPC value for adequate time for an execution task is 0.5.

Applying these factors yields the following:

$$\text{Radiation protection worker fails to check radiation levels} = 0.03 \times 0.8 \times 0.5 = 0.02$$

Radiation Protection Worker Misreads Radiation Level—The second potential way that the radiation protection worker could fail to properly determine that the shield ring is not properly in place is by simply misreading the meter on the radiation gauge and believing the level is acceptable. Therefore, this failure is misreading the digital display on the radiation monitor.

This can be represented by THERP (Ref. E8.1.26, table 20-11, item 1) (HEPs for EOCs in check-reading digital indicator displays).

Radiation protection worker misreads radiation level = 0.001

Radiation Monitor Fails—The radiation protection worker could also fail to properly determine that the shield ring is not properly in place due to a problem with the radiation monitor. The radiation monitor could give a false low reading as the result of a hardware failure. This is a mechanical rather than a human failure. From the Attachment C, Table C4-1, the failure rate for radiation sensors is approximately 2E−5/hour. It is expected that the monitor is used at least once each day. Using the equation for standby equipment (0.5λt) yields:

Radiation monitor fails = 0.5 × 2E−5 × 24 = 2.4E−4

Crew Member Fails to Note Shield Ring Is Out of Position Before Approaching TAD Canister—The crew members, after being cleared to begin the unbolting task, bring the required tools and approach the TAD canister. They have performed this task many times before, and they would have an image in their minds of how everything should look. Unlike the previous scenario, the ring is essentially in place and the misalignment is a more subtle deviation from the image they expect. The crew carries the tools they need, they are focused on the performance of the task, and likely talking to each other about the performance of the task or involved in casual conversation (since the work is not particularly difficult or challenging and they are not expecting any complications). The unsafe action is that they do not notice that the shield ring is out of position. The crew members would have a bias that the previous activities have been performed correctly, the shield ring is configured properly, and they are ready to proceed with their operations; any differences in appearance do not register (i.e., they see what they expect to see). To put this in a more colloquial context, this type of missed observation would be comparable to an individual walking up to their car and failing to notice that the door of the car is slightly ajar, up to the point of opening the door and getting in.

Although there is no specific check that takes place when the crew begins operations to partially drain the TAD canister, there is ample opportunity to notice that the shield ring is not properly in place (i.e., is over the TAD canister, but out of position). There is no risk of exposure until the TAD canister is partially drained because prior to that, the water would provide adequate shielding. The crew would be located in the vicinity of the TAD canister and have a clear view of any problems. They would have to not notice that the shield ring is out of place before they began draining the water. Rather than missing a check, it is more in the nature of failing to notice that the operational conditions were not correct. There are no failures in the primary quantification methods that reasonably fit this unsafe action, so it is necessary to provide a value based on expert judgment (ATHEANA). It is clear that some credit needs to be given for this since the crew members perform this task often and should recognize what the configuration should look like when they perform the task, especially given that they would be within a few feet of the TAD canister for several minutes performing preparatory tasks before the drain. However, in opposition to this, the crew begins operations on the TAD canister believing the shield ring is properly configured and they are focused on the task that they are about to perform. Taking all of this into consideration, the HRA team believes that the failure is unlikely, which corresponds to an HEP of 0.1.

Crew members fail to notice that shield ring is out of position
prior to approaching TAD canister = 0.1

Calculation for Scenario 1(b)—The events in the HEP model for Scenario 1(b) are presented in Table E6.9-5.

Table E6.9-5. HEP Model Events for HFE Group #9 Scenario 1(b) for 050-OpSTCShield1-HFI-COD

Designator	Description	Probability
A	Crane operator installs shield ring improperly	0.0004
B	Radiation protection worker fails to check radiation levels	0.02
C	Radiation protection worker misreads radiation level	0.001
D	Radiation monitor fails	0.00024
E	Crew member fails to note shield ring out of position before approaching TAD canister	0.1

NOTE: HEP = human error probability; HFE = human failure event; TAD = transportation, aging, and disposal.

Source: Original

The Boolean expression for this scenario follows:

$$A \times (B + C + D) \times E =$$
$$0.0004 \times (0.02 + 0.001 + 0.00024) \times 0.1 = 1E{-}6 \qquad \text{(Eq. E-45)}$$

E6.9.3.4.2.3 HEP for HFE 050-OpSTCShield1-HFI-COW

The Boolean expression for the overall HFE (all scenarios) follows:

050-OpSTCShield1-HFI-COW =
HFE 1(a) + HFE 1(b) =
5E−5 + 1E−6 = 6E−5

E6.9.4 Results of Detailed HRA for HFE Group #9

The final HEPs for the HFEs that required detailed analysis in HFE Group #9 are presented in Table E6.9-6 (with the original preliminary value shown in parentheses):

Table E6.9-6. Summary of Detailed Analysis for HFE Group #9

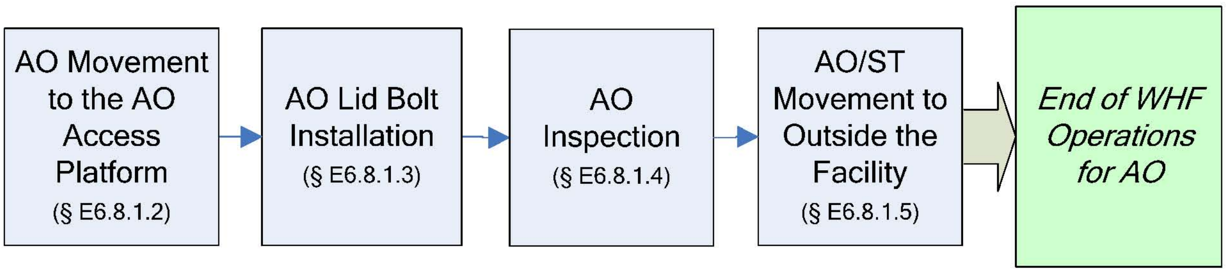
HFE	Description	Final Probability
050-OpSTCShield1-HFI-COD	Operator causes exposure due to failure to properly install STC shield ring	6E−5 (1E−02)

NOTE: HFE = human failure event; STC = shielded transfer cask.

Source: Original

E6.10 ANALYSIS OF HUMAN FAILURE EVENT GROUP #10: EXPORT OF A TAD CANISTER/AGING OVERPACK FROM THE WHF

HFE group #10 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6-0.1, covering export of a TAD canister in an aging overpack from the facility. The operations covered in this HFE group are shown in Figure E6.10-1. This operation begins with the aging overpack/TAD canister sitting in the CTM Loading Room with the aging overpack lid on, unbolted. The operation proceeds through movement of the aging overpack, on a site transporter, to the Site Transporter Vestibule where the aging overpack lid is bolted. The operation ends with the export of the aging overpack/site transporter from the facility.



NOTE: § = section; AO = aging overpack; HFE = human failure event; ST = site transporter; WHF = Wet Handling Facility.

Source: Original

Figure E6.10-1. Activities Associated with HFE Group #10

E6.10.1 Base Case Scenario

E6.10.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #10 activities.

1. The aging overpack (secured on a site transporter) is in the Cask Loading Room, loaded with a TAD canister, with an aging overpack lid on top, unbolted.

2. The site transporter is off with forks lowered.

4. There is an interlock between the port slide gates and the Cask Loading Room shield doors; the port slide gate cannot be open while the shield doors to the Cask Loading Room are also open.

The following personnel are involved in this set of operations:

- Crew members (two people)
- Supervisor
- Site transporter operator