Once the cask is fully upright, the crane operator stops raising the cask. The crane operator bases this on a visual inspection, confirmed by hand signals from the signaling crew member.

Cask Unbolting from Pivot Point—Without detaching the crane from the cask, the crew uses common tools and the MAP to unbolt the constraints on the bottom half of the cask so the cask can be lifted. This step is verified.

This ends the discussion of upending a VTC or HSTC. Section E6.2.1.5 discusses the process of upending a TTC, which includes an intermediate transfer to a cask preparation stand. Once the VTC is upright, it is then moved to the CTT (Section E6.2.1.6); once the HSTC is upright, it is then moved to the DPC cutting station (Section E6.2.1.7).

E6.2.1.5 Preparation of a TTC for Transfer to the CTT

As illustrated in Figure E6.2-1, the upending process for a VTC/HSTC and TTC are very similar, but not identical. The upending process for a TTC requires that the cask be removed from the conveyance and upended using a tilting frame with an intermediate transfer to a cask stand. This process is described in this section.

E6.2.1.5.1 Removal of Tie-downs

Crew members remove transportation cask tie-downs using common tools and handling equipment and the MAP. This step is identical to Section E6.2.1.4.2.

Once the impact limiters are removed, the crew removes the cask tie-downs in preparation to lift the transportation cask off the conveyance. Crew members remove transportation cask tie-downs using common tools and handling equipment and the MAP. This step is identical to Section E6.2.1.4.2. This operation is done on the conveyance. The crew is trained to execute this task. The crew removes all the bolts of the tie-down, with several crew members removing the bolts simultaneously. Once removed, the bolts are counted, and the crew supervisor checks off bolt removal. Once bolt removal is verified, the crane operator (using the 200-ton cask handling crane with cask sling) proceeds to lift the cask.

E6.2.1.5.2 Movement of Transportation Cask with Impact Limiters to Cask Stand

In this step the crane operator moves the transportation cask with impact limiters attached to the cask stand using the 200-ton cask handling crane with standard rigging. Prior to this step the cask stand is pre-staged in the appropriate place, the slings used to move the personnel barrier are removed from the crane, and the cask sling is attached to the crane.

Crane Movement to Transportation Cask—The crane operator moves the 200-ton cask handling crane so as to locate the crane over the transportation cask, following the indicated safe load path marked on the floor. The operator does this visually and also receives confirmatory hand signals 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 to Cask and Engagement of Sling—The crane operator lowers the crane into position so that the crew members can place the sling (which is connected to an I-beam) around the cask. Once in position, the crew members place the sling around the cask. The supervisor verifies, via checklist, that the sling is properly attached. The crane 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 operator's movement (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the cask, checking the placement of the sling. The verification crew member can only signal the crane operator to stop. Once the sling is secured around the cask, the crane operator initiates the lift, and the crew members ensure that, when lifted, the load is level. If the sling is not positioned properly and the load is not level, either crew member signals the crane operator to stop and lower the cask so that the sling can be repositioned.

Vertical Lifting of Cask—The signaling crew member signals the crane operator to lift the cask. The crane operator lifts the cask vertically until it clears the conveyance. The crane operator bases this on a visual inspection, confirmed by hand signals from the signaling crew member. Once the transportation cask is past the conveyance, the crane operator lowers the cask to the proper height for movement. The proper height for movement is defined as roughly 6 in. above the highest obstacle in the movement path. The crane operator determines the proper height based on visual inspection, confirmed by hand signals from the signaling crew member.

Cask Positioning over the Cask Stand—The operator moves the 200-ton cask handling crane so as to locate the cask over the cask stand, following the indicated safe load path marked on the floor. The operator determines the path visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member. Once aligned, the signaling crew member signals the crane operator to lower the cask. The crane operator lowers the cask, and then the crew members, ensuring stable placement, detach the slings from the crane. The crane operator then lifts the crane to the appropriate height for movement, confirmed by 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, guided by the signaling crew member, moves the crane to the cask sling stand, where the crew member removes the cask sling.

E6.2.1.5.3 Removal of Impact Limiters from Cask while on Cask Stand

The removal of impact limiters is identical to the operations discussed in Section E6.2.1.4.1, other than that the impact limiter removal occurs while the cask is on the cask pedestal.

Impact limiters are removed using the 20-ton auxiliary hook with standard rigging, common tools, and the cask access platform. This step is performed twice because each cask has two impact limiters.

In preparation for this step, the crew members and crane operator attach the impact limiter lifting device (uneven slings) to the 20-ton auxiliary hook.

Once the cask is positioned on the cask stand, the crew removes and stores the impact limiters. This operation is done on the cask stand according to training. The first step is to remove the restraining bolts on the impact limiters. Depending on the cask type, there can be anywhere from 24 to 36 bolts to remove, with several crew members removing the bolts simultaneously. Once removed, the bolts are counted, and the crew supervisor checks off bolt removal from the checklist. Once bolt removal is verified, the crane operator (using a 20-ton auxiliary hook) removes and stores the impact limiters.

Positioning Crane over Impact Limiter—The crane operator positions the crane over the impact limiter, following the indicated safe load path marked on the floor. The crane operator performs this task visually and also receives confirmatory hand signals 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 Impact Limiter—The crane operator lowers the crane into position over the impact limiter. The crane operator is positioned on the floor in view of the crew members on either side of the impact limiter. There is a signaling crew member next to the impact limiter who uses hand signals to guide the crane operator's movements (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the impact limiter, checking alignment of the crane. The verification crew member can only signal the crane operator to stop. Once positioned, one of the crew members connects the crane to the impact limiter using the uneven sling and integral lift points.

Vertical Lifting of Impact Limiter—Upon signal from the signaling crew member, the crane operator ensures that the impact limiter is free of the transportation cask (this may include moving the impact limiters horizontally to free them) and then begins to raise the impact limiter. Once the impact limiter has been raised (i.e., is hanging free) such that it has cleared the cask stand, the crane operator stops raising the impact limiters. The crane operator bases this on a visual inspection, and this is confirmed by hand signals from the signaling crew member. Once past the cask stand, the crane operator lowers the crane to the proper height for movement. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path. The crane operator determines the proper height based on a visual inspection, confirmed by hand signals from the signaling crew member.

Impact Limiter Positioning for Lowering—The crane operator moves the crane to locate the impact limiter over the position where it should be lowered in the staging area, following the indicated safe load path marked on the floor. The crew member does this visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Impact Limiter Lowering and Disengagement—When properly positioned and the placement area is clear, the signaling crew member signals the crane operator to lower the impact limiter. The crane operator lowers the impact limiter at or below the maximum allowable speed. Once the impact limiter is lowered, a crew member disengages the sling, and the crane is lifted to the maximum height in preparation for the next operation.

E6.2.1.5.4 Installation of Trunnions (if required)

Trunnions are installed onto the cask by using common tools, standard rigging, the cask handling crane (auxiliary hook), and the MAP. This step is identical to Section E6.2.1.4.3.

Crew members retrieve the trunnions to be installed. Trunnions are located in a package on the conveyance. If required, the 20-ton auxiliary hook is used to place the trunnions in the proper position. Crew members secure the trunnions according to training.

E6.2.1.5.5 Transportation Cask Movement to Cask Tilting Frame

In preparation for this step, the cask tilting frame is pre-staged in the preparation area. It is possible the cask stand is an integral component with the tilting frame, however, for this analysis they are considered separate entities, and the extra sling lift is required.

Transportation Cask Movement and Placement onto Tilting Frame—Once the tilting frame is in place and the impact limiters removed, the crane operator and crew members retrieve and attach the cask sling to the 200-ton cask handling crane.

Crane Alignment to Cask—The crane operator lowers the 200-ton cask handling crane into position so that the slings can be attached to the crane. The crane 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 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. Once in position, the other crew members attach the sling to the crane and ensure that, when lifted, the load is level. If the sling is not positioned and the load is not level, the signaling crew member signals the crane operator to stop and lower the object so that the sling can be repositioned.

Vertical Lifting of the Cask—Upon signal from the signaling crew member, the crane operator begins to raise the cask. Once the cask is raised to roughly 6 in. above the cask stand, the crane operator stops raising the cask, based on a visual inspection and confirmation by hand signals from the signaling crew member. The crane operator clears the cask stand and lowers the crane to the proper height for movement. The crane operator bases this on a visual inspection and a confirmatory 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.

Cask Positioning for Lowering—The crane operator moves the crane to position the cask over the tilting frame, following the indicated safe load path marked on the floor. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Cask Lowering and Disengagement of Sling—When properly positioned and the placement area is clear, the signaling crew member signals the crane operator to lower the cask onto the tilting frame. The crane operator proceeds to lower the cask at or below the maximum allowable speed. Once the cask is lowered and stable, a crew member disengages the sling, and the crane operator lifts the crane in preparation for the next operation.

Once the cask is on the tilting frame, the crew secures the transportation cask to the tilting frame using common tools and the cask handling platform. This step is guided by a procedure and is verified by a supervisor signature on a checklist before the cask is upended.

E6.2.1.5.6 Upending Transportation Cask Using Cask Tilting Frame

The transportation cask is upended using the tilting frame and 200-ton cask handling crane with yoke.

Once the cask is placed on the tilting frame, the crane operator and crew members place the cask sling on its stand and retrieve and attach the yoke. Once that is done, the crew proceeds to initiate the upending.

Crane Positioning over the Transportation Cask—The operator positions the crane over the transportation cask, following the indicated safe load path marked on the floor. The crane operator performs this task visually and also receives confirmatory hand signals 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 crane 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 using hand signals to guide the operator's movement (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. 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 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.

Vertical Positioning of Cask—Upon signal from the signaling crew member, the crane operator begins to raise the cask. Since the bottom of the cask remains stationary, the operator moves the crane to remain directly above the upper trunnions (i.e., to keep the cables straight). The crane operator visually performs this task and gets hand signals from the signaling crew member that the cask is "upending" properly. Once the cask is fully upended, the crane operator stops raising the cask, basing this on a visual inspection, confirmed by hand signals from the signaling crew member.

Cask Unbolting from Pivot Point—Without detaching the crane from the cask, the crew uses common tools and the MAP to remove the constraints from the tilting frame so the cask can be lifted. This step is verified.

This ends the discussion of preparing a TTC for transfer to the CTT (Section E6.2.1.6).

E6.2.1.6 Transportation Cask Movement to CTT (DPCs in VTCs and TTCs only)

Vertical Lifting of Cask—Once the cask is upended and unconstrained, 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 conveyance/tilting frame before lowering the cask to movement height.

Cask Positioning over CTT—The crane operator moves the crane to position the cask over the CTT, following the indicated safe load path marked on the floor. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member since the operator's view of the alignment "ring" on the CTT is obstructed. Once properly positioned, the signaling crew member signals the crane operator to lower the cask onto the CTT. The crane operator lowers the cask and, with the confirmation of the signaling crew member, disengages the yoke and lifts the crane to proper moving height.

Securing the Transportation Cask to the CTT—Once the cask is properly loaded, the crew member(s) secures the transportation cask to the CTT, which is like a cage that locks into position. There may be bumpers installed prior to closing the CTT door. This step is defined in training and must be signed off via a checklist prior to movement of the CTT.

E6.2.1.7 Movement of the HSTC to the DPC Cutting Station

This step is a continuation of Section E6.2.1.4 (upending the HSTC).

Once the HSTC is upended, without detaching the cask handling crane from the cask, the crane operator lifts the cask over the HCTT and aligns the cask at the DPC cutting station, following the indicated safe load path marked on the floor. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. A crew member opens the DPC cutting platform doors for the crane operator. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member since the operator's view of the platform alignment may be obstructed. Once properly positioned, the signaling crew member signals the crane operator to lower the cask. The crane operator lowers the cask and, with the confirmation of the signaling crew member, disengages the yoke and lifts the crane to proper moving height.

E6.2.1.8 Movement of the VTC with SNF to the Cask Preparation Station

This step is a continuation of Section E6.2.1.4 (upending the VTC).

Once the VTC is upended, without detaching the cask handling crane with cask handling yoke from the cask, the crane operator moves the cask to preparation station #1, #2, or #3.

Movement of the VTC to the Cask Preparation Area – The operator raises the cask to clear the railcar or truck trailer and 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 crane 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. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member that is on the opposite side of the cask of the signaling crew member. The verification crew member can only give the crane operator a signal to stop. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member since the operator's view of the alignment in the pit is obstructed. Once properly positioned, the crew member signals the crane operator to lower the cask. Because truck casks are smaller than other casks, the cask is placed into a transportation cask handling frame and the crew secures the cask to the frame by closing the frame door and ensuring it is locked into position.

E6.2.2 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 cask upending and removal are summarized in Table E6.2-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III; Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

Table E6.2-1. HFE Group #2 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
Crane Drops	*Operator Drops Cask during Upending and Removal*: To upend a cask and move it into the CTT, the operator must lift the cask using the cask handling crane. TTCs must be lifted three times: once to the cask stand using a sling, once to the tilting frame using a sling, and once to upend the cask and move it to the CTT using the yoke. VTCs and TTCs only require one lift using the cask handling yoke to upend the cask and move it to the CTT or cutting platform. During these lifts, the operator can cause the cask to drop by improperly engaging the sling or yoke, two-blocking the cask, or other such failures.	5, 6	N/A[a]	In this step the operator uses the cask handling crane and auxiliary hook to move the cask and other heavy objects. All casks have one cask lift using the cask handling crane with cask handling yoke. TTCs have two additional cask lifts using the cask handling crane with sling. There are three heavy-object lifts (a personnel barrier and two impact limiters) using the auxiliary hook and slings. Each of these lifts can potentially result in a drop. These 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/rigging types. Documentation for this failure can be found in Attachment C.
	Operator Drops Object on Cask during Upending and Removal: To upend a cask and move it into the CTT, the operator must lift several heavy objects over the cask using the cask handling crane auxiliary hook and standard rigging. These objects include the personnel barrier and the impact limiters (2). During these lifts, the operator can drop the object onto the cask by improperly connecting the object to the crane, two-blocking the object, or other such failures.	5, 6	N/A[a]	
050-OpTCImpact01-HFI-NOD	*Operator Causes an Impact Between Cask and SSC during Upending and Removal*: While performing crane operations, the operator can impact the cask in the following ways: 1. Impact to the cask while moving an object with the crane. 2. Impact to the cask with the crane hook. 3. Collide the cask into an SSC while moving the cask with the crane. 4. MAP lowers into the cask. 5. Bridge or trolley impacts end stop.	5, 6	3E−03	In this step the cask is moved from the conveyance ultimately to the CTT, DPC cutting station or SNF preparation station. 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: • Crane is moved outside its safe load path (i.e., operators cut corners). • Crane is moved in the wrong direction. • Failure to maintain proper vertical and horizontal distance between cask and SSCs during crane operations. • MAP lowers into cask. • Bridge or trolley impacts end stop. The operator must manually maintain movement within the safe load path. It is not unlikely for the operator to stray slightly from that path, or that an object may be slightly within that path. However, these crane operations are very slow and within clear direct view of three observers. For the whole operation, the likelihood of impacting a cask was assessed to be comparable to the railcar collision HFE (050-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) and was accordingly 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-OpSpurMove01-HFI-NOD	*Operator Causes Spurious Movement of the CTT while Cask is Loaded into the CTT*: The CTT is supposed to be deflated, with the control pendant stored during this operation. However, if the CTT is not in the proper configuration for loading, the operator can inadvertently cause the CTT to move. If this spurious movement occurs while the cask is being lowered into the CTT, the result is an impact to the cask.	6	1E−04	In this step the CTT is sitting in the Cask Preparation Area ready to be loaded with a cask. The CTT is deflated, with the control pendant stored. For operations in this step there are three observers with clear visibility, the operations are simple, 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. This error was considered to be extremely unlikely (0.0001) because it requires multiple human errors. It would require the CTT to be left inflated, the observers (the crane operator, two crew members, or the radiation protection worker) would have to fail to notice or fail to stop operations and deflate the CTT, and an operator would have to access the pendent and signal the CTT to move. This failure mode is only applicable to DPCs in a VTC or TTC.

INTENTIONALLY LEFT BLANK

Table E6.2-1. HFE Group #2 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpTipover001-HFI-NOD	*Operator Causes Cask to Tip Over*: If the crane rigging is attached to the cask, RC, TT, HCTT or CTT (either accidentally or purposefully) and the crane or conveyance moves, the cask/conveyance can potentially be tipped over. The following are contributors to this HFE: 1. Crane hook, grapple or rigging catches conveyance/cask. 2. Horizontal movement with the hook lowered and attached to the cask. 3. Crane travels in the wrong direction. 4. Cask not lifted high enough to clear the conveyance.	5, 6	1E−04	In this step there are several crane operations using both the cask handling crane and the auxiliary hook. For crane operations there are three observers with clear visibility, the operations are simple, the travel distances are short, the time the cask is vertical is small, 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 contributors to cask tipover include: • Crane hook, grapple, or rigging catches conveyance/cask. • Horizontal movement with hook lowered and attached to cask. • Crane travels in wrong direction. • Cask not lifted high enough to clear conveyance. 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 (infrequently, 0.1) and then the cask tipping would have to go unnoticed by all three observers. This is done in an open area with direct observation, and tipover is a slow process; therefore the value was adjusted by a further 0.1.
050-OpCollide001-HFI-NOD	*Operator Causes Low-speed Collision with RC, TT, HCTT, CTT or TTC*: Operator can cause an auxiliary vehicle to collide into a loaded RC, TT, HCTT or CTT while the conveyance is parked in the Cask Preparation Area. The operator can also cause the auxiliary vehicle to collide directly into a TTC while it is on the cask stand or in the tilting frame. If the speed governor of the auxiliary vehicle is properly functioning, then it is a low-speed collision.	5, 6	3E−03	In this step the cask is in several positions that are vulnerable to impact via collision: • A railcar, truck trailer, or HCTT is parked in the Cask Preparation Area, loaded with a cask. • CTT is parked in the Preparation Area, loaded with a cask. • TTC is on the cask stand or tilting frame on the floor of the Cask Preparation Area. Throughout this scenario there are three observers with clear visibility, the speed of auxiliary vehicles is low, the conveyance or cask is stationary, and the conveyance or cask is very visible. Procedural controls are expected to limit the number of other vehicles in the Cask Preparation Area during cask operations. The railcar, truck trailer, and HCTT have their brakes set, and the CTT is deflated so that they cannot move to collide into something; however, if the operators failed to set the brakes of the railcar/truck trailer/HCTT or failed to deflate the CTT, it is unlikely these conveyances, while loaded with a cask, would move significantly. As a result, the most likely possibility for a collision involving a cask is limited to collisions with forklifts or other auxiliary vehicles. This HEP was assigned the same preliminary probability as 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 railcar collision HFE has additional failure modes associated with movement of the SPM which are not applicable here.
050-OpFLCollide1-HFI-NOD	*Operator Causes High-speed Collision of Loaded Conveyance or Cask with Auxiliary Vehicle*: Operator can cause an auxiliary vehicle to collide into a loaded RC, TT, HCTT or CTT while the conveyance is parked in the Cask Preparation Area. The operator can also cause the auxiliary vehicle to collide directly into a TTC while it is on the cask stand or in the tilting frame. If the collision is due to the auxiliary vehicle speed governor malfunctioning, then it is a high-speed collision.	5, 6	1.0	An auxiliary vehicle (i.e., forklift) over speeds, resulting in a collision with the railcar, truck trailer, HCTT, CTT or TTC. In order for this to occur, the speed governor of the colliding vehicle must fail. To be conservative, unsafe actions that require an equipment failure to cause an initiating event are assigned an HEP of 1.0.

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

CTT = cask transfer trolley; DPC = dual-purpose canister; ESD = event sequence diagram; HCTT = cask tractor and cask transfer trailer; HEP = human error probability; HFE = human failure event; HRA = human reliability analysis; ID = identification; MAP = mobile access platform; N/A = not applicable; RC = railcar; SNF = spent nuclear fuel; SPM = site prime mover; SSC = structure, system, or component; SSCs = structures, systems, and components; TT = truck trailer; TTC = a transportation cask that is upended using a tilt frame; VTC = a transportation cask that is upended on a railcar.

Source: Original

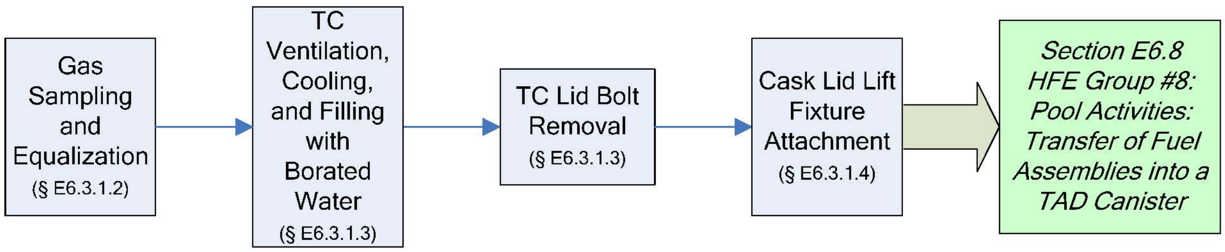
INTENTIONALLY LEFT BLANK

E6.2.3 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 (Ref. E8.2.1) performance objectives; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.3 ANALYSIS OF HUMAN FAILURE EVENT GROUP #3: SNF PREPARATION ACTIVITIES

HFE group #3 corresponds to the operations and initiating events associated with the ESD and HAZOP nodes listed in Table E6.0-1, covering activities that prepare SNF for transfer into the pool for unloading. This operation starts with the SNF in a transportation cask upright in the SNF preparation station. During this operation the transportation cask has a lid lift fixture attached and it undergoes gas sampling, equalization and cooling in preparation for movement into the pool.



NOTE: § = section; HFE = human failure event; TAD = transportation, aging, and disposal; TC = transportation cask.

Source: Original

Figure E6.3-1. Activities Associated with HFE Group #3

E.6.3.1 Base Case Scenario

E6.3.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #3 activities:

1. The transportation cask is sitting upright in the SNF preparation station.

2. The cask handling crane (200-ton) and auxiliary pool crane (20-ton) are in the Cask Preparation 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 design of 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 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
- Radiation protection worker[10]
- Supervisor
- Gas sampling crew member

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel. Personnel in the WHF wear the appropriate PPE for their job.

E6.3.1.2 Gas Sampling and Equalization

To sample the cask, a crew member must plug a hose into the quick-disconnect sampling port and then open the valve to start flow. Once connected, a crew member takes a reading in the gas sampling room of gas that is being removed and verifies that the cask is safe for opening. After the sample is taken, and if safe to do so, the remainder of the gas is vented, the valve is closed, and the hose is taken off.

E6.3.1.3 Transportation Cask Ventilation, Cooling, and Filling with Borated Water

After gas sampling is complete, a crew member checks the temperature readout from the sampling process and verifies that the temperature of the gas is less than 212°F. Once verified, a crew member connects the water supply and return lines to the cask via quick disconnect connections and then feeds the return line into the pool. Once the hoses are set up, a crew member slowly turns on the water and fills the cask until it is full. The cask is full when water, instead of air, flows from the return hose; this is indicated by a lack of bubbles coming from the return hose in the pool. When full, a crew member disconnects both hoses.

E6.3.1.3 Transportation Cask Lid Bolt Removal

The crew uses common tools and the SNF preparation platform to remove all but four of the lid bolts. This step is verified on a check list. Movement of the lid bolts may require the use of the

[10]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.

jib crane. Once removed, the bolts are counted, and the crew supervisor checks off bolt removal from the check list.

E6.3.1.4 Transportation Cask Lid Lift Fixture Attachment to Cask Lid

The crane operator uses the cask preparation platform, common tools, and the jib crane, with the lid lift fixture lifting device (expected to be a grapple), to retrieve and emplace the transportation cask lid lift fixture. Once in place, the crew members close the shield plate and attach the fixture to the lid with bolts via holes in the shield plate. This step is verified via a checklist.

Lid Lift Fixture Retrieval—The crane operator lowers the jib crane into position over the lid lift fixture in the staging area, engages the fixture, and lifts the fixture to proper height for movement, based on a 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.

Lid Lift Fixture Moved to Cask—The crane operator moves the jib crane so as to locate the fixture over the cask in the Cask Preparation Area, following the indicated safe load path marked on the floor. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member that can (hand) signal the crane operator to stop at any time. At this time, a crew member opens the shield plate to allow the fixture to be positioned. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Lid Lift Fixture Lowered and Disengaged—When properly positioned over the cask, the signaling crew member signals the crane operator to lower the fixture into place. The crane operator then proceeds to lower the fixture at or below the maximum allowable speed. Once the fixture is in place, the crane is disengaged from the fixture and then lifted to its maximum height in preparation for the next operation.

Shield Plate Closed and Lid Lift Fixture Bolted—The crew closes the shield plate and uses the cask preparation platform and common tools to emplace and tighten all the lid fixture bolts according to training and then verifies (via a checklist) that all the bolts have been properly installed.

The next step in WHF operations for SNF is Section E6.8, HFE Group #8.

E6.3.2 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 SNF preparation 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 E6.3-1. HFE Group #3 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpCaskDrop01-HFI-NOD	*Operator Drops Cask during Preparation Activities*: The cask is not lifted in this step, and no plausible scenarios that would lead to a cask drop could be identified.	8	N/A	The cask is not lifted in this step and the cask handling crane is not used in this operation. There is no plausible configuration that can result in a cask drop during this operation; therefore, this failure was omitted from analysis.
Crane Drop	*Operator Drops Object on Cask during Preparation Activities*: Preparation of a cask entails moving the lid lift fixture over the cask using the jib crane. During this lift, the operator can drop the object onto the cask by improperly connecting the object to the crane, two-blocking the object, or other such failures.	8	N/A[a]	In this step the operator uses the jib crane to move the lid lift fixture over the cask. The lid lift is moved with a grapple or hook. This lift can potentially result in a drop. This HFE was 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 this failure can be found in Attachment C.
050-OpCTCollide1-HFI-NOD	*Operator Causes Low-speed Collision of Auxiliary Vehicle with TC*: During SNF preparation, the TC is loaded and parked under the cask preparation platform for a long period of time. During this time, an operator can cause an auxiliary vehicle to collide with the TC.	8	3E−03	In this step the cask is sitting under the cask preparation platform. The speed of auxiliary vehicle is slow, the platform and cask are 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 value as 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 cask is staged under the platform and the railcar HFE has additional failure modes associated with movement of the SPM which are not applicable here. 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 (×3) because there are several ways for a collision to occur.
050-OpFLCollide1-HFI-NOD	*Operator Causes High-speed Collision of Auxiliary Vehicle with TC*: During cask preparation, the TC is loaded and parked under the preparation platform for a long period of time. During this time, an operator can cause an auxiliary vehicle to collide with the TC. If the collision is due to the auxiliary vehicle speed governor malfunctioning, then this is a high-speed collision.	8	1.0	The operator can cause the auxiliary vehicle to over speed, resulting in collision. In order to accomplish this, the speed governor of the vehicle must fail. To be conservative, unsafe actions that require an equipment failure to cause an initiating event are assigned an HEP of 1.0.
050-OpTCTImpact01-HFI-NOD	*Operator Causes an Impact Between SSC and Loaded TC due to Crane Operations*: While performing crane operations, the operator can potentially impact the cask if the crane is moved with the hook lowered below the platform.	8	3E−03	In this step the transportation cask is stationed under the preparation station and the lid lift fixture is moved over the cask. For crane operations in this step there are three observers with clear visibility, the operations are simple, the travel distances are short, and the crane speed is slow. There are no interlocks to prevent this error. No part of the cask is above the cask preparation platform. Therefore, the only way the transportation cask can be impacted with the crane is if the crane is moved with the load and hook lower than the platform, and the crane moves into the platform causing the load and hook to swing into the transportation cask. The likelihood of impacting a cask was assessed to be comparable to the crane impact during upending and removal HFE (050-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2) and was accordingly assigned the same preliminary value. This is considered a conservative assessment because, in comparison with upending and removal, there are fewer crane movements in this operation, and there is a platform around the cask which makes it harder to impact the cask. This failure is "highly unlikely" (one in a thousand or 0.001, which also corresponds to the generic failure rate for a simple operation that is performed daily) but is adjusted because there are several ways for an impact to occur (×3).
050-OpTipover001-HFI-NOD	*Operator Causes Cask to Tip Over during Cask Preparation Activities*: The operator can improperly stow the crane rigging and it can catch the cask. If this happens, movement of the crane can cause the cask to tip over.	8	1E−04	In this step the transportation cask is stationed under the cask preparation station and the lid lift fixture is attached to the cask lid. In order to get a tipover of the cask, the crane must be attached to the cask and must also move. To be conservative, the jib crane is considered physically capable of tipping over a cask while stationed underneath the platform. At no point in the operations is the crane attached to the cask. Therefore, the only way for the crane to be attached to the cask is if the crane rigging catches the cask during sampling. This is unlikely because the transportation cask is recessed under and protected by the platform during this operation. If the rigging is caught, then it is unlikely that the crane operator would not notice while trying to move the crane. 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 task is done under direct observation, there is a platform and a shield plate to protect the cask from stray rigging, and a tipover is a slow process. Therefore, the value was adjusted by a further 0.1. This operation was given the same preliminary value as the cask tipover during upending and removal HFE (050-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because it is a very similar operation (movement with a crane using the same type of rigging and attachments) and has similar failure modes. The difference between the two scenarios is that there are more crane operations and more failure modes during upending and removal, and therefore there would be more opportunities for a tipover in that scenario.
050-Liddisplace1-HFI-NOD	*Operator Inadvertently Displaces Lid*: The operator can improperly store the crane rigging such that it catches the lid lift fixture and pulls off the cask lid during cask preparation, resulting in a direct exposure.	29	N/A	In this step the lid lift fixture is attached. Also, in this step, the lid is bolted to the cask. Due to design changes to the preparation platform, improperly stowed rigging during this operation does not catch the lid lift fixture. These design changes included raising the platform so the cask is recessed underneath the platform. This failure was omitted from analysis.

INTENTIONALLY LEFT BLANK

Table E6.3-1. HFE Group #3 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpSampleRel2-HFI-NOD	*Operator Improperly Performs Gas Sampling*: Gas sampling may be performed to determine if the fuel has been damaged by the transportation process. If the gas sampling process is incorrectly performed, such that material is released from the sample line, then a radiation release occurs if the fuel inside is damaged.	16	5E−03	In this step, the crew samples the cask via a quick-disconnect gas sampling port to ensure that the fuel is intact before removing the canister lid. There is one operator in charge of gas sampling. In order to get a release from the line, the line would have to be inappropriately attached such that the quick disconnect valve is engaged and open. This EOC was assessed to be “highly unlikely” (0.001) because the operation is simple and performed on a daily basis by a highly trained individual. This value was adjusted (×5) to account for the fact that this operation is performed by one crew member, and a failure would be very difficult to notice and correct before material is released. Note: this is the probability of release if it is damaged fuel; for release of radioactivity to occur, the probability of damaged fuel would have to be assessed and applied.

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

EOC = error of commission; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; ID = identification; N/A = not applicable; SPM = site prime mover; SSC = structure, system, or component; TC = transportation cask.

Source: Original

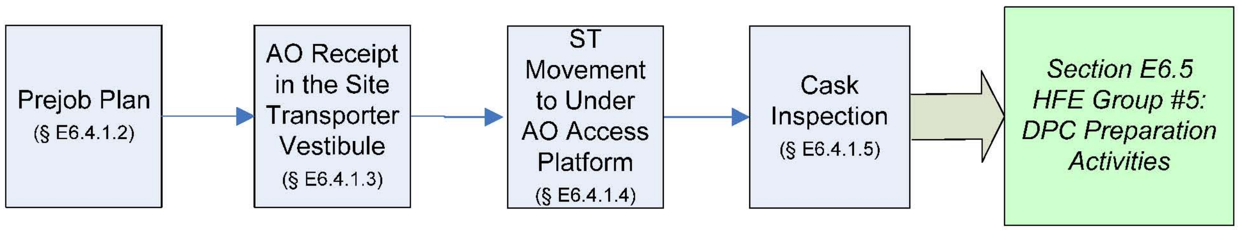
INTENTIONALLY LEFT BLANK

E6.3.3 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 (Ref. E8.2.1) performance objectives; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.4 ANALYSIS OF HUMAN FAILURE EVENT GROUP #4: SITE TRANSPORTER RECEIPT AND MOVEMENT INTO THE CASK PREPARATION AREA

HFE group #4 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering movement of a site transporter loaded with an aging overpack into the Site Transporter Vestibule to prepare it for unloading. The operations covered in this HFE group are shown in Figure E6.4-1. In this operation, a site transporter, carrying an aging overpack, enters the Site Transporter Vestibule and moves into position under the aging overpack access platform.



NOTE: § = section; AO = aging overpack; CTM = canister transfer machine; DPC = dual-purpose canister; HFE = human failure event; ST = site transporter.

Source: Original

Figure E6.4-1. Activities Associated with HFE Group #4

E6.4.1 Base Case Scenario

E6.4.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #4 activities.

1. The site transporter is securely loaded with an intact aging overpack and is at the entrance of the Site Transporter Entrance Vestibule.

The following personnel are involved in this set of operations:

- Crew members (two people)
- PIC
- Site transporter operator
- Radiation protection worker[11].

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel. Personnel in the WHF wear the appropriate PPE for their job.

[11] 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.

E6.4.1.2 Prejob Plan

Before the aging overpack and site transporter reaches the WHF, the PIC is notified of the type of cask and conveyance to expect and how to process it. According to this information, the PIC determines the appropriate procedures and equipment necessary to process this cask type and communicates this information to all the crew members involved in the processing of this cask. The PIC fills out a prelift safety checklist (i.e., per the DOE-STD-1090-2004 (Ref. E8.1.12)) verifying that the equipment is properly staged and is in proper operational condition. All crew members are properly trained and abide by the procedures of the facility.

E6.4.1.3 Aging Overpack Receipt in the Site Transporter Vestibule

Two crew members are located at the Site Transporter Vestibule. When the site transporter approaches the WHF, one crew member opens the outside overhead door and the other crew member directs the site transporter into the Site Transporter Vestibule, ensuring there are no vehicles or obstructions in the path. The crew members follow all relevant restrictions and procedures regarding site transporter speed and direction of travel. Once the site transporter has cleared the door, the first crew member closes the outside door.

E6.4.1.4 Site Transporter Movement to under the Aging Overpack Access Platform

Once the site transporter is in the Site Transporter Vestibule, the ST operator moves the site transport into position under the preparation platform, and stops. The brakes for the site transporter are set, the forks are lowered, the power is turned off, and, if required, the platform is closed over the site transporter.

A checklist is signed to indicate that the facility door has been closed and the site transporter brakes are set.

E6.4.1.5 Cask Inspection

Once the site transporter is parked in the facility, the crew visually inspects and conducts radiological surveys of the exterior of the aging overpack.

E6.4.2 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 receipt of the site transporter are summarized in Table E6.4-1. 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.

INTENTIONALLY LEFT BLANK

Table E6.4-1. HFE Group #4 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
ST Rollover	*Operator Causes the ST to Roll over in the ST Vestibule:* Operator drives over a significantly uneven surface while moving the ST into the ST Vestibule, causing the ST to roll over.	3	N/A	Although the center of mass for the ST is higher than that of the truck trailer, this failure mode was omitted from analysis for the same reasons as the truck rollover (Section E6.1). For an ST to roll over, the center of mass has to shift laterally. This can be done by traversing a significantly uneven surface or running over a very large object. There are no significantly uneven surfaces in the ST Vestibule. It is incredible for the ST to run over an object large enough necessary to shift its center of mass.
050-OpFailStop-HFI-NOD	*Operator Fails to Stop the ST if the Tread Fails*: If the tread of the ST fails, it is possible the ST can roll over if the operator continues to operate the ST.	3	1.0	If the tread of the ST fails, it is possible the ST can roll over if the operator continues to operate the ST. While it is unlikely that an operator would continue to operate an ST if such a significant and visible failure occurred, to be conservative, unsafe actions that require an equipment failure to cause an initiating event have been assigned an HEP of 1.0.
050-OpSTCollide3-HFI-NOD	*Operator Causes Low-speed Collision of ST with an SSC while Moving to the ST Vestibule*: Operator causes collision of ST with a facility structure or piece of equipment while moving into the ST Vestibule. The ST is physically unable to overspeed, therefore any collision of the ST is a low-speed collision.	3	3E−03	When the ST enters the WHF it can collide into an SSC, such as the facility door, an auxiliary vehicle, or improperly stowed crane rigging. Collision of an ST is a similar operation and has the same failure modes as the railcar collision HFE (050-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1), and was accordingly assigned the same preliminary value. This failure is "highly unlikely" (one in a thousand or 0.001) and was adjusted because there are several ways for a collision to occur and potentially multiple other vehicles (forklifts) that can collide into the conveyance (×3). In this case, the preliminary value is particularly conservative because no auxiliary vehicles are in the ST Vestibule; therefore, the only failure mode is for the ST to collide into the facility structure or the aging overpack access platform.
050-OpLoadDrop-HFI-NOD	*Operator Causes ST to Drop the AO*: The ST is like a forklift, carrying the AO several inches above the ground on its forks. If the AO is improperly secured onto the ST, it can fall off the forks while in transit.	3	N/A	There are no crane operations in this step, so the only way for an AO to be dropped is if it falls off the ST. The ST is like a fork lift which holds the AO raised several inches above the ground while in transit. The ST cannot lift the AO greater than one foot, so a drop greater than a foot is not plausible in this step. The AO is prevented from moving on or falling off the ST by a securing mechanism which locks the AO into place. The ST travels from the aging pads to the WHF. It is highly unlikely that the AO can drop in the facility due to human error given that it has not dropped in transit to the facility. Also, there are interlocks that prevent the ST from moving if the AO is not properly secured. Therefore, the drop of an AO due to human failure was omitted from the analysis.

NOTE: AO= aging overpack; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; ID = identification; N/A = not applicable; SSC = structure, system, or component; ST = site transporter.

Source: Original

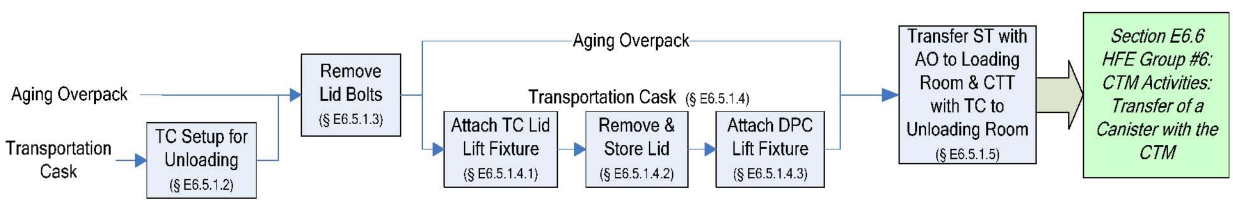
INTENTIONALLY LEFT BLANK

E6.4.3 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 (Ref. E8.2.1) performance objectives; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.5 ANALYSIS OF HUMAN FAILURE EVENT GROUP #5: DPC PREPARATION ACTIVITIES

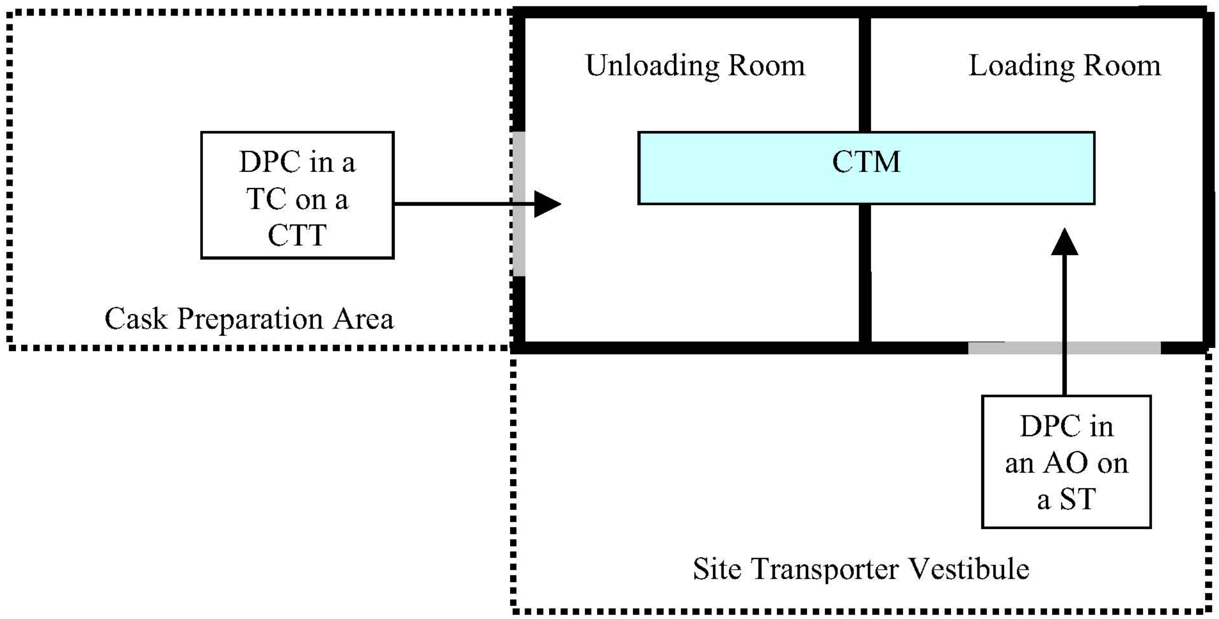
HFE group #5 corresponds to the operations and initiating events associated with the ESD and HAZOP nodes listed in Table E6.0-1, covering the preparation of an aging overpack or transportation cask containing a DPC for unloading from the conveyance and movement into position for removal of the DPC canister. Figure E6.5-1 provides an overview of the operations covered in this HFE group. The process of unloading a DPC from either an aging overpack or a transportation cask (VTC or TTC) is accomplished in one of two rooms on the WHF ground floor that can be accessed by the CTM. DPCs are removed from aging overpacks in the WHF Loading Room, because the Loading Room is the only room with CTM access that the site transporter can physically enter. DPCs are removed from transportation casks in the WHF Unloading Room because it is the only room with CTM access that the CTT can physically enter. This operation starts with the DPC in either an aging overpack under the aging overpack access platform in the Site Transporter Vestibule or in a transportation cask on the CTT in the Cask Preparation Area. During this operation the cask undergoes lid unbolting and other preparation activities necessary for canister transfer. Once the preparation activities are complete, the crew moves the aging overpack and site transporter to the Loading Room or the transportation cask and CTT to the Cask Unloading Room. In DPC is positioned under the cask port and is ready for CTM operations. Operations for this HFE group end at this stage, just prior to the start of CTM activities. Figure E6.5-2 provides a simplified schematic of the rooms involved in this operation.



NOTE: § = section; AO = aging overpack; CTM = canister transfer machine; CTT = cask transfer trolley; DPC = dual-purpose canister; HFE = human failure event; TC = transportation cask.

Source: Original

Figure E6.5-1. Activities Associated with HFE Group #5



NOTE: AO = aging overpack; CTM = canister transfer machine; CTT = cask transfer trolley; DPC = dual-purpose canister; ST = site transporter; TC = transportation cask; WHF = Wet Handling Facility.

Source: Original

Figure E6.5-2. Rooms Involved with the Preparation and Movement of DPCs at the WHF

E6.5.1 Base Case Scenario

E6.5.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #5 activities:

1. The transportation cask is intact and secure in the CTT under the cask preparation platform in the Cask Preparation Area. The aging overpack is intact and secure in the site transporter under the cask preparation platform in the Site Transporter Vestibule.

2. The CTT is an air-pallet trolley 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 the controller pendant stowed during preparation activities.

3. The site transporter is a fork-lift like apparatus that carries the aging overpack on prongs that are raised several inches above the ground. A safe load path is marked for the site transporter operations, and there are at least three crew members involved in its movement when loaded. The site transporter is normally powered off with the controller pendant stowed during preparation activities.

4. The shield doors to the Cask Unloading Room and Loading Room are closed. There is an interlock between the port slide gates and the shield doors. The port slide gate to a room cannot be open while the shield door to that room is also open.

5. The jib cranes (for both the preparation platform in the Cask Preparation Area and the aging overpack access platform in the Site Transporter Vestibule) have the following safety features:

   A. Upper limits—There are two upper limit marks: the initial is an indicator, and the final, that 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 designed 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 temperature interlock that cuts off power to the hoist when the motor 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.

- Crew members (two people)
- Crane operator
- Signaling crew member
- Verification crew member
- CTT operator
- Site transporter operator
- Radiation protection worker[12]
- Supervisor.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel. Personnel in the WHF wear the appropriate PPE for their job.

[12]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.

E6.5.1.2 Setup of Transportation Cask for Unloading (Transportation Cask Only)

Cask Preparation Platform Lowering (if Required) and Shield Plate Closure—Once the cask is loaded and secure in the CTT, the crew lowers the cask preparation platform (if necessary) and moves the shield plate over the cask.

Gas Sampling and Equalization (if Required)—To sample the cask, a crew member must plug a hose into the quick-disconnect sampling port and then open the valve to start the flow. Once connected, a crew member takes a reading in the gas sampling room of gas that is being removed and verifies that the cask is safe for opening. After the sample is taken, and if safe to do so, the remainder of the gas is vented, the valve is closed, and the hose is taken off.

E6.5.1.3 Remove Aging Overpack or Transportation Cask Lid Bolts

The crew closes the platform shield plate and removes all the cask or aging overpack lid bolts using the cask preparation platform and common tools. Movement of the lid bolts may require the use of the jib crane. Once removed, the bolts are counted and the crew supervisor checks off bolt removal from the check list before the site transporter is moved for CTM activities.

E6.5.1.4 Transportation Cask Preparation Activities

E6.5.1.4.1 Transportation Cask Lid Lifting Fixture Retrieval and Attachment to Cask Lid

The crane operator uses the cask preparation platform, common tools, and the jib crane, with lid lift fixture lifting device (i.e., a grapple) to retrieve and emplace the transportation cask lid lift fixture. Once in place, the crew members close the shield plate and attach the fixture to the lid with bolts. This step is verified via a checklist.

Lid Lift Fixture Retrieval—The crane operator lowers the jib crane into position over the lid lift fixture in the staging area, engages the fixture, and lifts the fixture to proper height for movement, based on a 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.

Lid Lift Fixture Moved to Cask—The crane operator moves the jib crane so as to locate the fixture over the cask in the Cask Preparation Area, following the indicated safe load path marked on the floor. The crane operator does this visually and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member that can (hand) signal the crane operator to stop at any time. At this time, a crew member opens the shield plate to allow the fixture to be positioned. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Lid Lift Fixture Lowered and Disengaged—When properly positioned over the cask, the signaling crew member signals the crane operator to lower the fixture into place. The crane operator then proceeds to lower the fixture at or below the maximum allowable speed. Once the fixture is in place, the fixture is disengaged, and the crane is lifted to its maximum height in preparation for the next operation.

Shield Plate Closed and Lid Lift Fixture Bolted—The crew closes the shield plate and uses the cask preparation platform and common tools to emplace and tighten all the lid fixture bolts according to training and then verifies (via a checklist) that all the bolts have been properly installed. The shield plate has holes by which the crew can access the lid fixture bolts.

E6.5.1.4.2 Transportation Cask Lid Removal and Storage on the Cask Lid Stand

Once the lid lift fixture is attached to the cask lid, the crew opens the shield plate and removes the transportation cask lid using the jib crane and standard rigging.

Crane Aligned to Cask—The crane operator retrieves the lid lift fixture lifting device, and the crew opens the shield plate. The crane operator then lowers the jib crane hoist cable into position over the transportation cask. The crane operator is positioned on the floor in view of the crew members on either side of the cask. There is a signaling crew member following the load 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 load, 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 to the cask lid using a grapple.

Lid is Lifted Vertically—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 CTT 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. Once the lid is removed, a crew member then closes the shield plate.

Lid Moved to Staging Area—The crane operator moves the jib crane so as to locate the lid over the lid stand in the staging 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.

E6.5.1.4.3 Retrieval and Attachment of DPC Lift Fixture to Transportation Cask

The lift fixture is attached to the DPC using the jib crane with a grapple or hook, cask preparation platform, and common tools. The crane operator and the signaling and verification crew members are positioned on the cask preparation platform for this step. There are several DPC types, and the DPC lift adapter is adjustable, with several mounting positions to accommodate all DPC types.

DPC Lift Fixture Retrieval—The crane operator lowers the jib crane into position over the DPC lift fixture in the staging area, engages the grapple, and lifts the fixture to 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.

DPC Lift Fixture Moved to Cask—The crane operator moves the jib crane so as to locate the fixture over the cask in the preparation 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. There is a verification crew member opposite the signaling crew member that can (hand) signal the crane operator to stop at any time. At this time, a crew member opens the shield plate to allow the fixture to be positioned. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

DPC Lift Fixture Lowered and Disengaged—When properly positioned over the DPC, the signaling crew member signals the crane operator to lower the fixture into place. The crane operator then proceeds to lower the fixture at or below the maximum allowable speed. Once the fixture is in place, the grapple is disengaged, and the crane is lifted to its maximum height in preparation for the next operation. The crane operator and crew stay several feet away from the platform opening while the shield plate is open.

Shield Plate Closed and DPC Lift Fixture Bolted—A crew member then closes the shield plate, uses the cask preparation platform and common tools to emplace and tighten all the lid fixture bolts according to training, and then verifies (via a checklist) that all the bolts have been properly installed. The shield plate has holes to enable the crew to access the lid fixture bolts.

E6.5.1.5 Transfer of the Site Transporter with an Aging Overpack to the Loading Room and the CTT with a Transportation Cask to the Cask Unloading Room

E6.5.1.5.1 Aging Overpack Movement into the Loading Room

Once the lid bolts are removed, the site transporter operator turns on the site transporter, lifts the fork several inches, and moves the site transporter to the door of the Cask Loading Room. A crew member opens the shield door and the site transporter operator moves the site transporter into position under the cask port in the Loading Room. There are physical stop points which the site transporter must bump up against to ensure proper alignment. The site transporter operator lowers the site transporter forks, turns off the site transporter and closes the shield door.

E6.5.1.5.2 Transportation Cask Movement into Cask Unloading Room

Using the CTT, the crew member moves the transportation cask 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, positions it under the cask port, deflates the CTT, stores the pendant, disconnects the air hose, and closes the shield door. There are physical stop points in the Cask Unloading Room that the CTT must bump up against to ensure proper alignment.

E6.5.2 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 cask preparation and movement to the Cask Unloading or Loading Room are summarized in Table E6.5-1. 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.

INTENTIONALLY LEFT BLANK

Table E6.5-1. HFE Group #5 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpCaskDrop01-HFI-NOD	*Operator Drops the Cask during Preparation Activities*: The cask is not lifted in this step, and no plausible scenarios that would lead to cask drop could be identified.	7, 9	N/A	The cask is not lifted in this step and the 200-ton crane is not used in this operation. For aging overpacks with DPCs, there is no possible configuration that can result in a cask drop because there is no crane capable of lifting an aging overpack in the Site Transporter Vestibule. For transportation casks with DPCs, a cask drop would require several human failures during the same set of activities: during lid removal, the crew must fail to remove some fraction of the lid bolts (EOO), fail to properly use a checklist to verify bolt removal, and must use the wrong crane (EOC) to remove the partially attached lid. In addition to the human failures, the bolts would have to hold the weight of the cask long enough to lift the cask. The crane operator and at least two other crew members would be standing on the platform in direct view of the cask during lid removal, and they would also all have to fail to notice that the entire cask is being lifted before the bolts break. This failure was omitted from the analysis.
Crane Drop	*Operator Drops an Object on Cask during Preparation Activities*: Preparation of a cask entails moving several heavy objects over the cask using a jib crane. These objects include the lid lift fixture and, for TC/DPCs, the cask lid and canister lift fixture. During these lifts, the operator can drop the object onto the cask or canister by improperly connecting the object to the crane, two-blocking the object, or other such failures.	7, 9	N/A[a]	In this step the operator uses the cask handling crane auxiliary hook to move objects over the cask. There are three heavy-object lifts (the lid lift fixture, the cask lid, and the canister lift fixture) using the auxiliary hook. The lid lift and canister lift fixtures are moved with a grapple or hook, the cask lid is moved with a sling. Each of these lifts can potentially result in a drop. These 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 this failure can be found in Attachment C. This failure mode is only applicable to transportation casks with DPCs because lid bolts are not heavy enough to damage an aging overpack.
050-OpCTCollide1-HFI-NOD	*Operator Causes Low-speed Collision of an Auxiliary Vehicle with the CTT*: During cask preparation, the CTT is loaded and parked under the preparation platform for a long period of time. During this time, an operator can cause an auxiliary vehicle to collide with the CTT. There are no auxiliary vehicles in the ST Vestibule, and so this failure mode is not applicable to AOs with DPCs.	7, 9	3E−03	In this step the CTT is loaded and parked under the cask preparation platform. 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 value 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 cask preparation platform, and the railcar collision HFE has additional failure modes associated with movement of the SPM that are not applicable here. 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 (×3) because there are several ways for a collision to occur.
050-OpFLCollide1-HFI-NOD	*Operator Causes High-speed Collision of Auxiliary Vehicle with the CTT*: During cask preparation, the CTT is loaded and parked under the preparation platform for a long period of time. During this time, an operator can cause an auxiliary vehicle to collide with the CTT. If the collision was due to the auxiliary vehicle speed governor malfunctioning, this failure would be a high-speed collision. There are no auxiliary vehicles in the ST Vestibule, and so this failure mode is not applicable to AO/DPCs.	7, 9	1.0	The operator can cause the auxiliary vehicle to over speed, resulting in collision. In order to accomplish this failure, the speed governor of the vehicle must fail. To be conservative, unsafe actions that require an equipment failure to cause an initiating event have generally been assigned an HEP of 1.0.
050-OpSpurMove01-HFI-NOD	*Operator Causes Spurious Movement of the CTT or ST during Preparation Activities*: The CTT is supposed to be deflated, with the control pendant stored during this operation. The ST is supposed to be turned off, with the control pendant stored during this operation. However, if the CTT/ST is not in the proper configuration for cask preparation, the operator can inadvertently cause the CTT/ST to move. This spurious movement can cause the CTT/ST to collide into the platform or other SSC.	7, 9	1E−04	In this step the CTT and site transporter are parked under a platform; the CTT is deflated, the site transporter is turned off and both have their control pendant stored. For operations in this step, there are several crew members on the preparation platform and no operators below the platform. This error was considered to be extremely unlikely (0.0001) because it requires multiple human errors: it would require the CTT to be left inflated or the site transporter to be left powered, the observers (i.e., the crane operator, two crew members, or the radiation protection worker) would have to fail to notice or fail to stop operations to deflate the CTT or turn off the site transporter, and an operator would have to access the pendent and signal the CTT or site transporter to move.

INTENTIONALLY LEFT BLANK

Table E6.5-1. HFE Group #5 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpCTTImpact1-HFI-NOD	*Operator Causes an Impact between an SSC and a Loaded CTT/ST due to Crane Operations*: While performing crane operations, the operator can potentially impact the cask if the crane is moved with the hook lowered below the platform.	7, 9	3E−03	In this step the CTT is stationed under the preparation platform and the lid lift fixture, lid (DPC only) and canister lift fixture (DPC only) is moved over the cask. The site transporter is parked under the aging overpack platform and has its lid bolts removed. For crane operations in this step, there are three observers with clear visibility, the operations are simple, the travel distances are short, and the crane speed is slow. There are no interlocks to prevent this error. No part of the cask is above the preparation platform, and so the only way the site transporter/CTT (containing a cask) can be impacted with the crane is if the crane is moved with the load/hook lower than the platform and the crane moves into the platform, causing the load/hook to swing into the site transporter/CTT. The crane hook can also be improperly stowed such that the site transporter/CTT, when moving to the Loading/Unloading Room (respectively), collides with the crane hook. However, the site transporter/CTT travels under the platform to the Loading/Unloading Room (respectively) and is the last preparation activity for both types of conveyances and requires the shield plate to be closed. Therefore, it is unlikely in this case that if the crane is improperly stored, the hook would be in the path of the CTT or site transporter. The likelihood of impacting a cask was assessed to be comparable to the crane impact during upending and removal HFE (050-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2) and was accordingly assigned the same preliminary value based on the following rationale: this failure is "highly unlikely" (one in a thousand or 0.001, which also corresponds to the generic failure rate for a simple operation that is performed daily) but is adjusted because there are several ways for an impact to occur (×3). This is assessment considered a conservative assessment because, in comparison with upending and removal, there are fewer crane movements in this operation, and there is a platform around both the CTT and site transporter which makes it harder to impact the CTT/site transporter.
050-OpTipover001-HFI-NOD	*Operator Causes Cask to Tip Over during Cask Preparation Activities*: The operator can improperly stow the crane rigging and it can catch the CTT, ST or cask. If this happens, movement of the crane or the CTT/ST can cause the cask to tip over.	7	1E−04	In this step the CTT is stationed under the cask preparation platform, the lid lift fixture is attached to the cask lid and the CTT is then moved to the Unloading Room. For aging overpacks with DPCs, the site transporter is stationed under the aging overpack platform, the lid bolts are removed, and the site transporter is then moved to the Loading Room. In order to get a tipover of the cask/CTT/site transporter, the crane must be attached to the cask or CTT/site transporter and the crane or CTT/site transporter must also move. To be conservative, the jib crane was considered physically capable of causing the cask/CTT to tip over underneath the platform; however, the jib crane cannot cause a loaded ST to tipover (Section 6.0 of the main report). At no point in the operations is the crane attached to the cask. For a transportation cask, the crane is attached to the lid, but the lid is unbolted (Section E6.0.2.3.2 provides a discussion of failure to remove lid bolts). Therefore, the only way for the crane to be attached to the cask is if the crane rigging catches the cask or CTT. This is unlikely because the CTT is protected by the platform and shield plate during this operation. If the rigging is caught, it is unlikely that the crane operator would not notice while trying to move the crane. It is also unlikely that, when the CTT begins movement to the Unloading Room, the operator and observers would not notice that the rigging is attached to the conveyance. 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 task is done under direct observation, there is platform and shield plate to protect the cask from stray rigging, and a tipover is a slow process; therefore, the value was adjusted by a further 0.1. This operation was given the same preliminary value as the cask tipover during upending and removal HFE (050-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because it is a very similar operation (movement with crane using same type of rigging/attachments) and has similar failure modes. The difference between the two scenarios is that there are more crane operations and more failure modes during upending and removal, and so there would be more opportunities for a tipover in that scenario; also, there is no platform/shield plate in upending to protect the cask from stray rigging.
050-OpTipOver3-HFI-NOD	*Operator Causes a Tipover of CTT/ST during Movement to the Cask Unloading/Loading Room*: The operator can improperly stow the crane rigging, and it can catch the CTT/ST or cask. If this happens while the CTT is moving to the Cask Unloading Room or the ST is moving to the Loading Room, it can cause the CTT/ST to tip over.	10, 11	N/A	The CTT/ST, loaded with a cask, undergoes a set of operations that includes operations under the preparation platform and then movement of the CTT/ST away from the platform to the Cask Unloading or Loading Room (respectively). A tipover of the CTT/ST during this set of activities constitutes one HFE because the most likely scenario is that the crane would be attached during preparation and a tipover would happen during movement of the CTT/ST away from the platform. The event sequences, however, model a tipover during platform activities and a tipover during CTT/ST movement. Because this is only one human failure, the appropriate preliminary value was only modeled in the event sequence associated with platform activities (050-OpTipover001-HFI-NOD, modeled in ESD 7). The HEP for a tipover in the event sequence associated with the subsequent movement of the CTT or ST (050-OpTipOver3-HFI-NOD in ESD 10 and 11) was assigned a probability of zero to avoid double counting.

INTENTIONALLY LEFT BLANK

Table E6.5-1. HFE Group #5 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpImpact0000-HFI-NOD	*Operator Causes Impact of Cask during Transfer from the Platform to Loading/Unloading Room*: While the ST is moving from the platform to the Loading Room and the CTT is moving to the Unloading Room, the ST/CTT can impact the crane hook or rigging if it is improperly stowed.	10	N/A	While moving from the Preparation Area to the Loading/Unloading Room, the CTT or site transporter can impact the crane hook or rigging if it is improperly stowed. The last step in preparation activities for both DPCs requires the shield plate of the platform to be closed. It is unlikely, then, that the crane rigging can be improperly stowed such that it impacts the CTT or site transporter while it is moving into the Unloading or Loading Room; it is more likely that rigging impacts the cask while the crane is actually in use. Therefore, any crane interference with the CTT/site transporter is already covered by 050-OpCTTImpact1-HFI-NOD (Operator Causes Impact between CTT or Site Transporter and SSC during DPC Preparation) and 050-OpTipover001-HFI-NOD (Operator Causes Cask to Tip Over during DPC Preparation Activities).
050-OpCTCollide2-HFI-NOD	*Operator Causes Low-speed Collision of the CTT during Transfer from the Preparation Station to the Cask Unloading Room*: Once the preparation activities are over, an operator inflates the CTT and moves the cask from the Preparation Area to the Unloading Room. The operator can cause the CTT to collide with the preparation platform structure 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 moves from the cask preparation platform to the Unloading Room; the doors of the Cask Preparation Area must be opened to allow the CTT to pass through. There are three observers with clear visibility, the speed of the CTT and other vehicles is low, the CTT is very visible, and there are two guide rails and an end stop to keep the CTT on the safe load path. Procedural controls are expected to limit the number of other vehicles in the Preparation Area during cask operations. The CTT could collide into conveyance or facility structures (i.e., cask preparation platform or shield door). This could happen if the guide rails were not installed properly. This operation is simple, straightforward, and 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 is less likely than a railcar collision because of the guide rail, number of observers, and short travel distance.
050-OpSTCollide3-HFI-NOD	*Operator Causes Low-speed Collision of the ST with an SSC while Moving to the Loading Room*: Operator causes a collision of the ST with a facility structure or piece of equipment while moving under the platform to the Loading Room. The ST is physically unable to overspeed, so any collision of the ST is a low-speed collision.	11	3E−03	While traveling to the Loading Room from the Site Transporter Vestibule, the site transporter can collide into an SSC, such as the shield door or the platform. Collision of a site transporter is a similar operation and has the same failure modes as the railcar collision HFE (050-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1), and was accordingly assigned the same preliminary value based on the following rationale: this failure is “highly unlikely” (one in a thousand or 0.001, which also corresponds to the generic failure rate for a simple operation that is performed daily) but is adjusted because there are several ways for collision to occur (×3).
050-OpFailStop-HFI-NOD	*Operator Fails to Stop ST if Tread Fails*: If the tread of the ST fails, it is possible that the ST can rollover if the operator continues to operate the ST while trying to move through the facility.	11	1.0	If the tread of the site transporter fails, it is possible the site transporter can rollover if the operator continues to operate the site transporter. While it is unlikely that an operator would continue to operate a site transporter if such a significant and visible failure occurred, to be conservative, unsafe actions that require an equipment failure to cause an initiating event are assigned an HEP of 1.0.
050-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance*: Once the preparation activities are over, an operator inflates the CTT or turns on the ST and moves the cask from the Preparation Area to the Loading or Unloading Room, respectively. There is a shield door between the Preparation Area and the Unloading Room and between the ST Vestibule and the Loading Room. The operator can impact the cask by inadvertently closing the shield door on the CTT or ST as they pass through the shield door.	12	1.0	The CTT and site transporter pass through a shield door as they enter the Loading/Unloading Room (respectively). During this transfer, the operator can close the shield door onto the CTT or site transporter. Section E6.0.2.3.3 provides a justification of this preliminary value.
050-OpDPCShield1-HFI-NOW	*Operator Fails to Properly Shield DPC while Installing Canister Lift Fixture, Leading to Direct Exposure (TC only)*: In this step, the DPC canister lift fixture is attached to the canister. There are two ways for the crew to get a direct exposure during this activity: an operator can fail to properly close and verify the closure of the shield plate after the cask lid is removed and the crew continues with the installation, or the operator can inadvertently open the shield plate while the crew is installing the canister lift fixture.	29	1E−03	In this step, the DPC canister lift fixture is attached to the canister. If an operator fails to properly close the shield plate after removing the DPC lid, then the crew can be directly exposed to the shine from the DPC while installing the canister lift fixture. Likewise, if an operator inadvertently opens the shield plate while the crew is installing the canister lift fixture, then the crew can be exposed. In this case, the crew is on top of the shield plate and notices if the shield plate moves. The crew is highly trained and, although they only perform DPC preparation activities weekly, they are accustomed to operating the shield plate during preparation of other transportation casks. In addition to the crew members, there is also a radiation worker present who is monitoring activities. This error was assessed to be highly unlikely and given a preliminary value of 0.001.
050-Liddisplace1-HFI-NOD	*Operator Inadvertently Displaces Lid*: The operator can improperly store the crane rigging such that it catches the lid lift fixture and pulls off the cask lid during cask preparation, resulting in a direct exposure.	29	N/A	In this step, the lid is unbolted and, for transportation casks with DPCs, other crane operations are performed. Due to design changes to the preparation platform, improperly stowed rigging during this operation does not catch the lid lift fixture. These design changes include raising the platform and adding a shield plate so the cask is recessed underneath the platform and protected.

INTENTIONALLY LEFT BLANK

Table E6.5-1. HFE Group #5 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
Gas Sampling	*Operator Improperly Performs Gas Sampling*: Gas Sampling is performed to determine if an incoming canister has been damaged by the transportation process. If the gas sampling process is incorrectly performed and a damaged canister goes undetected, then a radiation release occurs by continuing with normal operations.	29	N/A	If the gas sampling process is incorrectly performed and a damaged canister goes undetected, then a radiation release occurs by continuing with normal operations. Assessing accident scenarios with pre-damaged canisters is beyond the scope of this analysis.

NOTE: [a]Historical data was used to produce a probability for this HFE (Attachment C).

AO = aging overpack; CTT = cask transport trolley; DPC = dual-purpose canister; SSC = structure, system, or component; ST = site transporter; TC = transportation cask.

Source: Original

INTENTIONALLY LEFT BLANK

E6.5.3 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 E6.5.3.2.

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 E6.5.3.3 and E6.5.3.4, 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 E6.5.3.4. 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 E6.5.4.

E6.5.3.1 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 E6.5-2.

Table E6.5-2. Group #5 HFEs Requiring Detailed Analysis

HFE	Description	Preliminary Value
050-OpDPCShield1-HFI-NOW	Operator fails to properly shield DPC while installing canister lift fixture, leading to direct exposure	1E−03

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

Source: Original

E6.5.3.2 Assessment of Potential Vulnerabilities (Step 5)

For those HFEs requiring detailed analysis, the first step in the ATHEANA approach to 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 above. 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.

E6.5.3.2.1 Operating Team Characteristics

Crew members—There are several crew members involved in the installation of the canister lift fixture. One predesignated crew member operates the platform shield plate. This crew member, referred to here as the shield plate operator, is trained as to when the shield plate must be opened or closed. When the operations require the shield plate to be moved, the crew member informs the other crew members on the platform that the shield plate is going to be moved. The other crew members confirm that the shield plate is in the proper position before continuing on to the next step of the operation. All crew members are expected to have the proper training commensurate with nuclear industry standards. This training is followed by a period of observation until the operator is proficient.

Radiation protection worker—The radiation protection worker is a fully certified health physics technician, whose job is to monitor radiation from the cask during movement. 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.

E6.5.3.2.2 Operation and Design Characteristics

Preparation operations are slow and tedious, and they promote complacency.

The position of the shield plate is very visible. The shield plate is opened to place the canister lift fixture on the DPC, and it is then closed to bolt the fixture. The shield plate remains closed while the DPC is transferred to the Cask Unloading Room.

Shield Plate Operations—The shield plate has two modes: a normal travel mode (forward and reverse) and a jog mode (forward and reverse). The jog mode only allows the plate to move very slowly and in small increments. The shield plate operator uses the travel mode to move the shield plate completely over the cask port until it reaches the end stop. The jog function is then used for fine control of the shield plate to line up the shield plate with the bolt holes in the canister lift fixture. To open the shield plate, the shield plate operator again uses the normal travel mode until it reaches the end stop at the other end of the platform. Before opening or closing the shield plate, the shield plate operator ensures that the path of the shield plate is clear of personnel.

E6.5.3.2.3 Formal Rules and Procedures

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

E6.5.3.2.4 Operator Tendencies and Informal Rules

Observation and Communication—The shield plate crew member communicates the actions to other crew members throughout this operation. The entire crew should be aware of the procedure and order of operations.

E6.5.3.2.5 Operator Expectations

Anticipatory Actions—The preparation process is simple but time consuming. There can be a tendency for the crew to focus on future tasks while preparing the DPC.

Consequences of Failure—The cask is not lifted in this step, and a shield plate is over the cask, so the threat of radiation release or physical injury is very low in this procedure. The crew expects failures to be relatively inconsequential, which promotes complacency in the operations.

E6.5.3.3 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 they are then refined through discussions with subject matter experts from a wide range of areas, as described in Section E4.2.

Table E6.5-3 summarizes all of the HFE scenarios developed for the HFE in this group.

Table E6.5-3. HFE Scenarios and Expected Human Failures for HFE Group #5

HFE	HFE Scenarios
050-OpDPCShield1-HFI-NOW *Operator fails to properly shield DPC while installing canister lift fixture, leading to direct exposure*	HFE Scenario 1(a): (1) Shield plate crew member does not place shield plate entirely over the cask, or (2) crew fails to notice improper shield plate closure before approaching the shield plate. HFE Scenario 1(b): (1) Shield plate crew member opens shield plate while crew bolts canister lift fixture, or (2) crew fails to notice shield plate movement in time OR shield plate crew member fails to respond to warnings from crew.

NOTE: HFE = human failure event.

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), (3), etc. 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 E6.5-3.

The HFE scenarios summarized in Table E6.5-3 are discussed and quantified in detail below.

E6.5.3.4 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, structured hierarchically by each HFE category (identified by a basic event name); the HFE scenario; and then the unsafe actions under each scenario, as previously documented in Table E6.5-3.

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.

E6.5.3.4.1 Common Values Used in the HFE Detailed Quantification

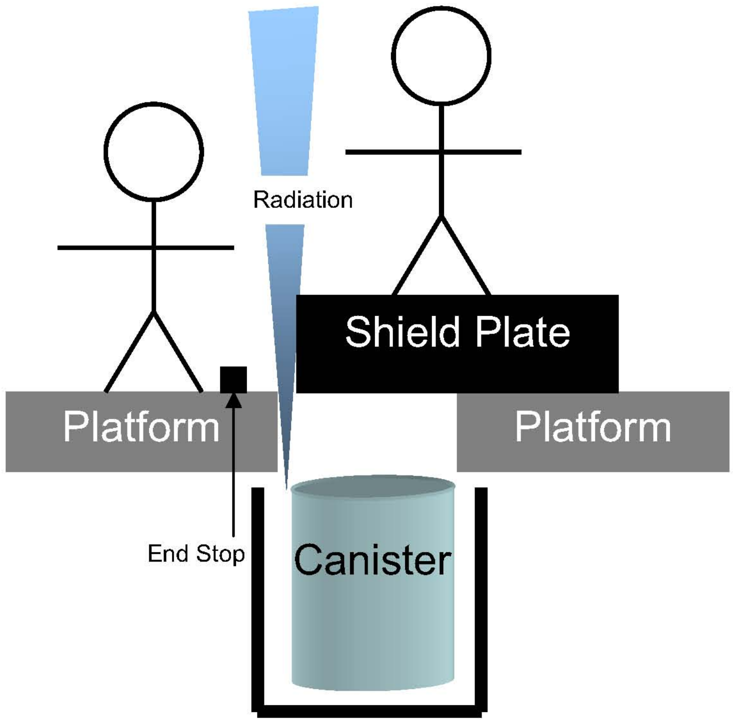
There are some mechanical failures that combine with unsafe actions to form HFEs. In general, these mechanical failures are independent of the specific HFE scenario, and so they can be quantified independently. These values are presented in this section.

Interlock Failures—There are a number of interlock failures in the HFE scenarios. While the status of these events can affect subsequent events in the scenarios in different ways, the likelihood of this event occurring is independent of the scenario. This event is an equipment failure and does not have a human component to its failure rate. The demand failure rate for an interlock, from Attachment C, Table C4-1, is approximately 2.7E−05 per demand.

Interlock fails to perform function = 2.7E−05

E6.5.3.4.2 Quantification of HFE Scenarios for 050-OpDPCShield1-HFI-NOW: Operator Fails to Properly Shield DPC while Installing Canister Lift Fixture, Leading to Direct Exposure

Figure E6.5-3 is an illustration of this failure scenario; this figure is not to scale. The DPC itself is shielded on top. The radiation of concern in this scenario is streaming from the small portion of the annulus which is not covered by the preparation platform. Because the shield plate is so visible and because the crew cannot access the canister to bolt the canister lift fixture to the DPC without the shield plate, the only scenarios considered in this analysis are those in which the shield plate is partially open; failure to close the shield plate entirely has been omitted from analysis.



Source: Original

Figure E6.5-3. 050-OpDPCShield1-HFI-NOW Operator Failure Scenario

E6.5.3.4.2.1 HFE Group #5 Scenario 1(a) for 050-OpDPCShield1-HFI-NOW

1. Shield plate crew member fails to cover cask entirely with shield plate.
2. Crew fails to notice improper shield plate closure before approaching the shield plate.

Shield Plate Crew Member Fails to Cover Cask Entirely with Shield Plate—After the canister lift fixture is placed on the DPC, the shield plate operator ensures that the platform area around the shield plate path is clear, announces that the shield plate is closing, and holds down the forward control of the shield plate until it hits the end stop. At that point, the shield plate operator stops moving the shield plate and informs the crew that they can begin their bolting procedure. This process may have some degree of automation; however, to be conservative, this process is analyzed as if it is entirely manual. This is a simple manual action that the operator performs on a regular basis based on training.

The shield plate operator action of closing the shield plate until it hits the end stop is a simple manual action that the operator performs several times a day based on training. Operation of the shield plate is always the same. The end stop provides an indication, or feedback, that the shield plate has been appropriately moved. This error most closely corresponds to the task execution error NARA (Ref. E8.1.11) generic task type (GTT) A1, and it is adjusted by the following EPCs:

- GTT A1: Carry out a simple single manual action with feedback. Skill-based and therefore not necessarily with procedures. The baseline HEP is 0.005.

- 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 assessed proportion of affect (APOA) anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This assessment appears reasonable for this task since the closure operation takes place in just minutes, so the APOA is set at 0.1.

Shield plate crew member fails to cover cask entirely
with shield plate = $0.005 \times [(3-1) \times 0.1 + 1] = 0.006$

Crew Fails to Notice Improper Shield Plate Closure before Approaching the Shield Plate— If the crew fails to notice that the shield plate is not entirely closed before they approach the shield plate to begin bolting operations, they can potentially get a direct exposure while getting onto the platform. The bolting crew has to get onto the shield plate in order to bolt the canister lift fixture. Part of their training is to visually confirm the shield plate position before approaching the plate. The shield plate, platform opening, and end stop are all easily visible from the preparation platform. This error most closely corresponds to the observation error CREAM (Ref. E8.1.18) cognitive function failure (CFF) O3, adjusted by the following CPCs with values not equal to 1.0.

- CFF O3: Observation not made. The baseline HEP is 0.003.

- CPC "Working Conditions": The crew is physically present with a good view of the area, which qualifies as advantageous. The CPC for advantageous working conditions for an observation task is 0.8.

- CPC "Adequacy of Training/Preparation": Training is adequate, with high experience. The CPC for an observation task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Crew fails to notice improper shield plate closure before
approaching the shield plate = $0.003 \times 0.8 \times 0.8 = 0.002$

This is the HEP if the action is completely independent on the part of the crew. However, there is a dependency between the shield plate operator's failure to close the shield plate properly and the crew's failure to notice based on a certain level of trust between the unbolting crew and their crewmate working the shield plate. In normal, low-consequence circumstances, this dependency might be considered "medium" or "high"; however, in this scenario, the crew is directly at risk if the shield plate operator fails, and thus more likely to actually perform the check. Therefore, this dependency was assessed to be "low." From THERP (Ref. E8.1.26, Table 20-21, item (a)(2)), the revised probability of this unsafe action follows:

Crew fails to notice improper shield plate closure
before approaching the shield plate = 0.05

HEP Calculation for Scenario 1(a)—The events in the HEP model for Scenario 1(a) are presented in Table E6.5-4.

Table E6.5-4. HEP Model for HFE Group #5 Scenario 1(a) for 050-OpDPCShield1-HFI-NOW

Designator	Description	Probability
A	Shield plate operator fails to cover cask entirely with shield plate	0.006
B	Crew fails to notice improper shield plate closure before approaching the shield plate	0.05

Source: Original

The Boolean expression for this scenario follows:

$$A \times B = 0.006 \times 0.05 = 0.0003 \quad \text{(Eq. E-1)}$$

E6.5.3.4.2.2 HFE Group #5 Scenario 1(b) for 050-OpDPCShield1-HFI-NOW

1. Shield plate crew member opens the shield plate while the crew bolts the canister lift fixture.

2. The crew fails to notice the shield plate movement in time OR the shield plate crew member fails to respond to warnings from the crew.

Shield Plate Crew Member Opens Shield Plate while Crew Bolts Canister Lift Fixture— While it is likely that the entire crew involved in cask preparation is trained in proper shield plate operations, during normal cask preparation operations, the only crew member authorized to open the shield plate is the predesignated shield plate operator. The shield plate operator is trained to ensure that the shield plate and shield plate path are cleared of personnel before moving the shield plate. Also, there is a direct view of the entire shield plate path from the shield plate control location.

The shield plate is not supposed to be moved again during cask preparation activities once the canister lift fixture has been placed on the DPC. The only operations that occur after the canister lift fixture is emplaced and the shield plate is closed are bolting of the fixture and then movement of the CTT to the Cask Unloading Room. Neither of these actions requires actions that can be confused with the actions that correspond to operating the shield plate; bolting requires tools, and CTT movement is not done from the platform.