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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 only require one lift, using the cask handling yoke to upend the cask and move it to the CTT. 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.	3	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 two impact limiters. 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.	3	N/A[a]	
060-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: - Impact cask while moving object with crane - Impact cask with crane hook - Collide cask into SSC while moving cask with crane - Mobile access platform lowers into cask - Bridge or trolley impacts end stop.	3	3E−03	In this step the cask is moved from the conveyance ultimately to the CTT. For crane operations in this step, there are three observers with clear visibility, the operations are simple, the travel distances are short, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a very regular (daily) basis. There are no interlocks to prevent this error. The dominant contributors to the impact of a cask include the following: - Crane moved outside its safe load path (e.g., operators cut corners) - Crane moved in wrong direction - Operator failed to maintain proper vertical and horizontal distance between cask and SSCs during crane operations - Mobile access platform lowered into cask - Bridge or trolley impacts end stop. The operator must manually maintain movement within the safe load path. It is not unlikely that the operator would stray slightly from that path or that an object would be slightly within that path. However, the crane operations are very slow and within clear, direct view of three observers. The likelihood of impacting a cask was assessed to be comparable to the railcar collision HFE (060-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).
060-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.	3	1E−04	In this step the CTT is sitting in the Cask Preparation Room 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 (i.e., 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.
060-OpTipover001-HFI-NOD	*Operator Causes Cask to Tip over*: If the crane rigging is attached to the cask, RC, TT, or CTT, either accidentally or purposefully, and the crane or conveyance moves, the cask can potentially tip over. The following are contributors to this HFE: - 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.	3	1E−04	In this step there are several crane operations using both the cask handling crane and the auxiliary crane. For crane operations in this step, there are three observers with clear visibility, the operations are simple, the travel distances are short, the time the cask is vertical is 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 contributors to cask tipover include the following: - Crane hook, grapple, or rigging catches conveyance/cask. - Horizontal movement with hook lowered and causes hook to attach 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 (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.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
060-OpCollide001-HFI-NOD	*Operator Causes Low-Speed Collision with RC, TT, CTT, or TTC*: Operator can cause an auxiliary vehicle to collide into a loaded RC, TT, or CTT while the conveyance is parked in the Cask Preparation Room. 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, it is a low-speed collision.	3	3E−03	In this step the cask is in several positions that are vulnerable to impact via collision: - The railcar or transfer trailer is parked in the Cask Preparation Room, loaded with a cask. - The CTT is parked in the Cask Preparation Room, loaded with a cask. - The TTC is on the cask stand or tilting frame on the floor of the Cask Preparation Room. Throughout this scenario there are three observers with clear visibility, the speed of auxiliary vehicles is low, the conveyance or cask is stationary and very visible. Procedural controls are expected to limit the number of other vehicles in the Cask Preparation Room during cask operations. The railcar and transfer trailer have their brakes set, and the CTT is deflated, so they cannot move to collide into something; however, if operators failed to set the brakes of the railcar or transfer trailer 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 value as railcar collision HFE (060-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 screening value is conservative because the railcar or transfer trailer collision HFE has additional failure modes associated with movement of the SPM that are not applicable here.
060-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, or CTT while the conveyance is parked in the Cask Preparation Room. 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, it is a high-speed collision.	3	1.0	The operator can cause an auxiliary vehicle (e.g., forklift) to overspeed, resulting in collision with the railcar, transfer trailer, CTT, or TTC. In order to accomplish this, 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 generally assigned an HEP of 1.0.

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

CTT = cask transfer trolley; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; ID = identification; N/A = not applicable; RC = railcar; 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

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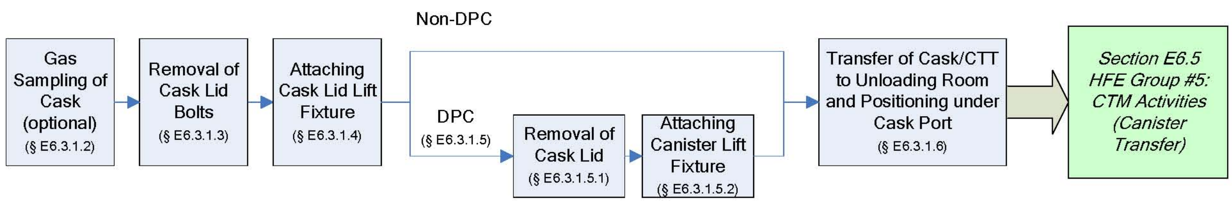
E6.2.3 Detailed Analysis

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 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: CASK PREPARATION AND MOVEMENT TO CASK UNLOADING ROOM

HFE group #3 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering cask preparation activities and movement of the cask to the Cask Unloading Room. The operations covered in this HFE group are shown in Figure E6.3-1. This operation starts with the transportation cask upright and secured in the CTT. During this operation the cask undergoes gas sampling, equalization, and other preparation activities necessary to leave the Cask Preparation Room. All casks have their lid bolts removed and a lid lift fixture installed, but DPCs also have the cask lid removed and a canister lift fixture installed onto the DPC. Once the preparation activities are complete, the crew moves the transportation cask from the Cask Preparation Room to the Cask Unloading Room and positions the cask under the cask port, ready for CTM operations. This operation ends at this point, prior to any CTM activities.



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

Source: Original

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

E6.3.1 Group #3 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 intact and secure in the CTT.

2. The cask handling crane (200-ton and 20-ton) has the following safety features:

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

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

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

- The shield door to the Cask Unloading Room is closed. There is an interlock between the port slide gates and the shield doors; the port slide gate cannot be open while the shield doors are also open.

The following personnel are involved in this set of operations:

- Crane operator
- Signaling crew member
- Verification crew member
- Radiation protection worker[10]
- Supervisor.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel.

E6.3.1.2 Gas Sampling of Cask

Platform is Lowered (if Required) and Shield Plate is Closed—Once the cask is loaded and secure in the CTT, the crew lowers the platform, if necessary, and moves the shield plate over the cask.

Gas Sampling and Equalization are Performed (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 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 should be vented, the valve closed, and the hose taken off.

[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.

E6.3.1.3 Removal of Transportation Cask Lid Bolts

The crew uses common tools, the preparation platform, and the shield plate to remove all the cask lid bolts. Movement of the lid bolts may require the use of the auxiliary crane. Once removed, the bolts are counted, and the crew supervisor checks off bolt removal before the lid is removed or the lid lift fixture is attached.

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

The crane operator uses the cask preparation platform, common tools, and the 20-ton auxiliary crane, with 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. This step is verified via a checklist.

Lid Lift Fixture Retrieval—The crane operator lowers the 20-ton auxiliary 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 20-ton auxiliary crane so as to locate the fixture over the cask in the Cask Preparation Room, 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.

As illustrated in Figure E6.3-1, for DPCs, additional preparation activities are needed (Section E6.3.1.5). All other waste forms can be transferred directly to the Cask Unloading Room (Section E6.3.1.6).

E6.3.1.5 Other Preparation Activities (DPC Only)

Casks containing DPCs must undergo additional preparation activities, including removal of the cask lid (Section E6.3.1.5.1) and attachment of a canister lift fixture (Section E6.3.1.5.2).

E6.3.1.5.1 Removal and Storage of the Transportation Cask Lid 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 20-ton auxiliary 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 20-ton auxiliary crane 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 next to the personnel barrier 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 cask, 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 the 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 20-ton auxiliary 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 hook.

E6.3.1.5.2 Retrieval and Attachment of DPC Lift Fixture

The lift fixture is attached to the DPC using the 20-ton auxiliary 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 20-ton auxiliary crane into position over the DPC lift fixture in the staging area, engages the hook, 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 20-ton auxiliary 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.

E6.3.1.6 Cask Transfer Via CTT to Cask Unloading Room (All Casks)

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.

E6.3.2 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 cask preparation and movement to the Cask Unloading Room 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 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
060-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 cask drop could be identified.	4	N/A	The cask is not lifted in this step, and the 200-ton crane is not used in this operation. For non DPCs, there is no possible configuration that can result in a cask drop. For 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 analysis.
Crane drop	*Operator Drops Object on Cask during Preparation Activities*: Preparation of a cask entails moving several heavy objects over the cask using the cask handling crane auxiliary hook. These objects include the lid lift fixture and, for 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.	4	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 (i.e., 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, and the cask lid is moved with a sling; the canister lift fixture and cask lid lifts are only applicable to the preparation of DPCs. 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.
060-OpCTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of Auxiliary Vehicle with CTT*: During cask preparation, the CTT is loaded 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.	4	3E−03	In this step the CTT is loaded and parked under the 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 Room during cask operations. This HEP was assigned the same preliminary value as railcar collision HFE (060-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) because the dominant mechanism of both failures is collision with an auxiliary vehicle. In this case, the preliminary value is conservative because the CTT is staged under the platform, and the railcar–truck trailer 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.
060-OpFLCollide1-HFI-NOD	*Operator Causes High-Speed Collision of Auxiliary Vehicle with CTT*: During cask preparation, the CTT is loaded 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 is due to the auxiliary vehicle speed governor malfunctioning, this failure would be a high-speed collision.	4	1.0	The operator can cause the auxiliary vehicle to overspeed, 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 been assigned an HEP of 1.0.
060-OpSpurMove01-HFI-NOD	*Operator Causes Spurious Movement of CTT during Preparation Activities*: 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 cask preparation, the operator can inadvertently cause the CTT to move. This spurious movement can cause the CTT to collide into the preparation platform.	4	1E−04	In this step the CTT is parked under the preparation platform; the CTT is deflated, with the 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, 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 and deflate the CTT, and an operator would have to access the pendent and signal the CTT to move.
060-OpCTTImpact1-HFI-NOD	*Operator Causes an Impact Between SSC and Loaded CTT 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.	4	3E−03	In this step the CTT is stationed under the Cask Preparation Room and the lid lift fixture, lid (DPC only), and canister lift fixture (DPC only) are 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 preparation platform, and so the only way the CTT (containing a 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 CTT. The crane hook can also be improperly stowed such that the CTT, when moving to the Cask Unloading Room, collides with the crane hook. However, the CTT travels under the platform to the Cask Unloading Room, and the last preparation activity for both DPCs and non-DPCs requires the shield plate to be closed, so it is unlikely in this case that, if the crane is improperly stored, the hook would be in the path of the CTT. The likelihood of impacting a cask was assessed to be comparable to the “Crane Impact during Upending and Removal” HFE (060-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2) and was accordingly assigned the same preliminary value. This assessment is considered conservative because, in comparison with upending and removal, there are fewer crane movements in this operation, and there is a platform around the CTT that makes it harder to impact the CTT. 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).

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
060-OpTipover002-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 or cask. If this happens, movement of the crane or the CTT can cause the cask and CTT to tip over.	4	1E−04	In this step the CTT is stationed under the preparation station, the lid lift fixture is attached to the cask lid and the CTT is then moved to the Cask Unloading Room. In order to get a tipover of the cask or CTT, the crane must be attached to the cask or CTT, and the crane or CTT must also move. To be conservative, the 20-ton crane is considered capable of physically tipping over the cask while it is in a CTT underneath the platform. At no point in the operations is the crane attached to the cask; for DPC preparation, 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, which 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 attempting to move the crane. It is also unlikely that, when the CTT begins movement to the Cask Unloading Room, the CTT operator and observers would not notice that the rigging is attached to the CTT. 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 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 (060-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because it is a very similar operation (i.e., movement with crane using the same type of rigging and attachments). The difference between the two scenarios is that there are more crane operations and more failure modes during upending and removal, so there would be more opportunities for tipover in that scenario; also, there is no platform/shield plate in upending to protect the cask from stray rigging.
060-OpTipOver3-HFI-NOD	*Operator Causes Tipover of CTT during Movement to the Cask Unloading Room*: The operator can improperly stow the crane rigging, and it can catch the CTT or cask. If this happens while the CTT is moving to the unloading room, it can cause the CTT to tip over.	6	N/A	The CTT, loaded with a cask, undergoes a set of operations that includes operations under the preparation platform and then movement of the CTT away from the platform to the Cask Unloading Room. Tipover of the CTT during this set of activities constitutes one HFE because the most likely scenario is that the crane would be attached during preparation and tipover would happen during movement of the CTT away from the platform. The event sequences, however, model tipover during platform activities *and* tipover during CTT movement. Because this is only one human failure, the appropriate preliminary value was only modeled in the event sequence associated with platform activities (060-OpTipover002-HFI-NOD, modeled in ESD 4). The HEP for tipover in the event sequence associated with the subsequent movement of the CTT (060-OpTipOver3-HFI-NOD in ESD 6) was assigned a probability of zero to avoid double counting.
060-OpImpact0000-HFI-NOD	*Operator Causes Impact of Cask during Transfer from Cask Preparation Room to Cask Unloading Room*: While moving from the Cask Preparation Room to the Cask Unloading Room, the CTT can impact the crane hook or rigging if it is improperly stowed.	6	N/A	While moving from the Cask Preparation Room to the Cask Unloading Room, the CTT can impact the crane hook or rigging if it is improperly stowed. The last step in preparation activities for both DPCs and non-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 would impact the site transporter while it is moving out of the Cask Unloading Room; it is more likely that rigging would impact the cask while the crane is actually in use. Therefore, any crane interference with the CTT is already covered by 060-OpCTTImpact1-HFI-NOD ("Operator Causes Impact between CTT and SSC during Cask Preparation with Lid On") and 060-OpTipover002-HFI-NOD ("Operator Causes Cask to Tip Over during Cask Preparation Activities").
060-OpCTCollide2-HFI-NOD	*Operator Causes Low-Speed Collision of CTT during Transfer from Cask Preparation Room to Cask Unloading Room*: Once the preparation activities are over, an operator inflates the CTT and moves the cask from the Cask Preparation Room to the Cask 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.	6	1E−03	In this step the CTT moves from the preparation station to the Cask Unloading Room; the doors of the preparation station 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 Cask Preparation Room during cask operations. The CTT could collide into a conveyance or a facility structure (e.g., the preparation station platform). This failure could happen if the guide rails were not installed properly. This operation is simple, is straightforward, is expected to occur very regularly (daily), and was assigned the default probability of a "highly unlikely" occurrence (0.001). It was considered reasonable and consistent that the preliminary value assigned for this HFE be less likely than a railcar–truck trailer collision because of the guide rail, number of observers, and short travel distance.
060-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance*: Once the preparation activities are over, an operator inflates the CTT and moves the cask from the Cask Preparation Room to the Cask Unloading Room. There is a shield door between the Cask Preparation Room and the Cask Unloading Room. The operator can impact the cask by inadvertently closing the shield door on the CTT as the CTT passes through the door.	7	1.0	The railcar or transfer trailer passes through shield doors as it enters the Cask Preparation Room. During this transfer, the operator can cause the CTT to collide into the shield door or can close the shield door on the CTT. Section E6.0.2.3.3 provides a justification of this preliminary value.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
060-OpDPCShield1-HFI-NOW	*Operator Causes Loss of Shielding while Installing DPC Lift Fixture*: 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 an operator can inadvertently open the shield plate while the crew is installing the canister lift fixture.	17	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 would notice if the shield plate moved. 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 was given a preliminary value of 0.001.
060-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.	17	N/A	In this step the lid is unbolted, and the lid lift fixture is attached. Due to design changes to the preparation platform, improperly stowed rigging during this operation would 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
Gas sampling	*Operator Improperly Performs Gas Sampling*: Gas sampling may be 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, a radiation release can occur by continuing with normal operations.	N/A	N/A	If the gas sampling process is incorrectly performed and a damaged canister goes undetected, a radiation release would occur by continuing with normal operations. Assessing accident scenarios with previously damaged canisters is beyond the scope of this analysis.

NOTE: [a] HRA value replaced by use of historic data.
CTT = cask transfer trolley; DPC = dual-purpose canister; EOC = error of commission; EOO = error of omission; 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.

Source: Original

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E6.3.3 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 E6.3.3.2.

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 E6.3.3.3 and E6.3.3.4, 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 E6.3.3.4. 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 E6.3.4.

E6.3.3.1 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 CRCF 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 E6.3-2.

Table E6.3-2. Group #3 HFE Requiring Detailed Analysis

HFE	Description	Preliminary Value
060-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

E6.3.3.2 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.

E6.3.3.2.1 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.

E6.3.3.2.2 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.

E6.3.3.2.3 Formal Rules and Procedures

Procedures—There are no written, formal procedures that the crew has in front of them during cask preparation; the procedures for how to handle a DPC come from training.

E6.3.3.2.4 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.

E6.3.3.2.5 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.

E6.3.3.3 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 E6.3-3 summarizes all of the HFE scenarios developed for the HFE in this group.

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

HFE	HFE Scenarios
060-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 E6.3-3.

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

E6.3.3.4 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 E6.3-3.

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.

E6.3.3.4.1 Common Values Used in the HFE Detailed Quantification

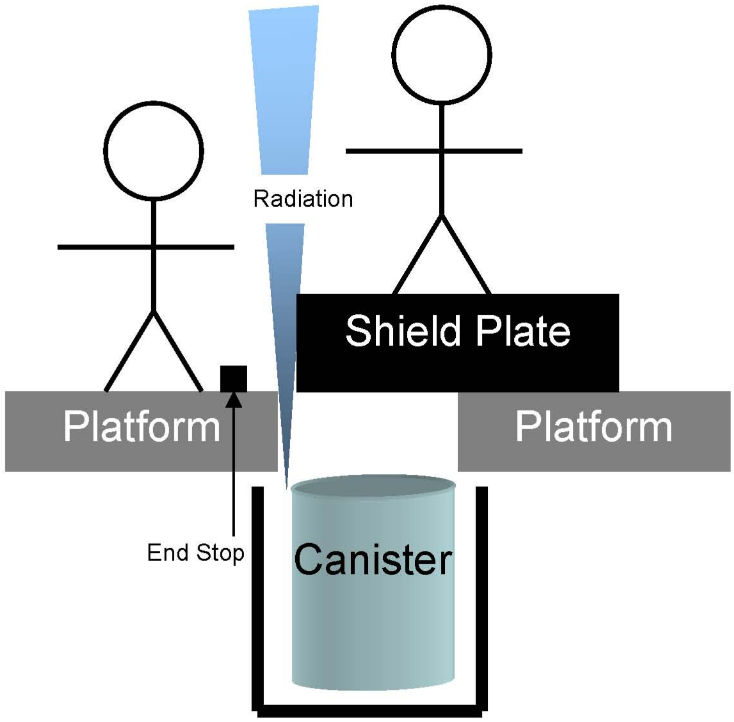
There are some mechanical failures that combine with unsafe actions to form HFEs. In general, these mechanical failures are independent of the specific HFE scenario, and so they can be quantified independently. These values are presented in this section.

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

E6.3.3.4.2 Quantification of HFE Scenarios for 060-OpDPCShield1-HFI-NOW: Operator Fails to Properly Shield DPC while Installing Canister Lift Fixture, Leading to Direct Exposure

Figure E6.3-2 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 E6.3-2. 060-OpDPCShield1-HFI-NOW Operator Failure Scenario

E6.3.3.4.2.1 HFE Group #3 Scenario 1(a) for 060-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 under load/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 E6.3-4.

Table E6.3-4. HEP Model for HFE Group #3 Scenario 1(a) for 060-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:

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

E6.3.3.4.2.2 HFE Group #3 Scenario 1(b) for 060-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.

Once the canister lift fixture is placed on the DPC and the shield plate is closed, the shield plate is not supposed to be opened for the remainder of the operations. Therefore, this error is an EOC. The crew who are on the shield plate bolting the canister lift fixture would immediately notice that the shield plate was moving and would signal the person committing this error to stop. THERP (Ref. E8.1.26) Table 20-12 describes several EOCs. None of these errors, however, appropriately describes this error. EOCs described in THERP (Ref. E8.1.26) primarily refer to actions where the operator intends to perform an action (e.g., flip a switch or turn a knob) but performs a different action (e.g., flips the wrong switch or turns the knob the wrong way). In this case, none of crew members would be performing an action similar to opening the shield plate during this step. They would only be installing bolts in the canister lift fixture. The most appropriate error that corresponds with this HFE was determined to be the task execution error NARA (Ref. E8.1.11) GTT A5, adjusted by the following EPCs:

- NARA GTT A5: Task execution. Completely familiar, well-designed, highly practiced routine task performed to highest possible standards by highly motivated, highly trained and experienced person, totally aware of implications of failure, with time to correct potential errors. The baseline HEP is 0.0001. While this error is not a task execution error (because there is no task being performed) this error was considered the most appropriate because it describes the operations the best. This value is considered to be conservative when applied to this failure because there is no task being performed in this step.

- EPC 13: Operator under load/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. This EPC is applicable in its full effect because the whole set of cask preparation activities is slow and tedious, and the operator could get bored and distracted and believe it is time to open the shield before the workers are completely clear. This is the only relevant EPC, and the APOA is set at 1.0.

Using the NARA (Ref. E8.1.11) HEP equation yields the following:

Shield plate crew member opens shield plate while crew bolts canister lift fixture

$$= 0.0001 \times [(3-1) \times 1.0 + 1]) = 0.0003 \qquad \text{(Eq. E-2)}$$

Crew Fails to Notice Shield Plate Movement in Time—During this portion of the operation, there are several people on the shield plate bolting the fixture with long reach tools that go through the shield plate. If the shield plate is inadvertently opened, these crew members would notice and provide immediate feedback to the person operating the plate. The crew would have roughly 30 seconds to notice and try to warn the shield plate operator. If they failed to notice the movement or did not realize what it meant, they would be exposed.

The crew works on the platform and stands on the shield plate or very close to it. Their reaction to it is a very simple response to a very obvious indicator; in this case the indicator is movement of the shield plate. This would be very obvious to the workers present, and they would have on the order of 30 seconds to react. While the NARA task execution error GTT C1 is primarily applicable to response to indicators in a control room, it is seen as the most applicable failure mode to this scenario because the basic action is, again, a very simple response to a very obvious indicator. Specifically, the portions of the description of GTT C1 related to “simple diagnosis required” and “response must be direct execution of simple actions” were considered applicable to this action. The other human failure quantification option for this action might be CREAM generic failure type I3 for “delayed interpretation”; however, the CREAM CPCs did not allow the influence of unfamiliarity to be fully addressed. Therefore, it is considered that NARA GTT

C1 captures both the observation and interpretation characteristics of the action, adjusted by the following EPCs:

- GTT C1: Simple response to a range of alarms or indications providing clear indication of situation (simple diagnosis required). The baseline HEP is 0.0004.

- EPC 2: Unfamiliarity (a potentially important situation that occurs infrequently or is novel). The full affect EPC would be ×20, which applies to a rare event not covered in training, but procedures exist. The APOA anchor for 0.5 is for a rare event covered once per year in training. The APOA anchor for 0.1 is for a rare event covered in regular training. Other considerations for a reduction from full affect is something rarely practiced but easy to carry out and for which the crew has some familiarity. This is covered in regular health physics training and in health physics procedures. Proper health physics practices and the importance of shielding is emphasized in the training. It appears reasonable for this task that the APOA be set at 0.1.

- EPC 3: Time pressure. The full affect would be ×11, which applies if, in order to complete the required task, the operator would have to complete each task step correctly and as quickly as possible. The anchor example for the full effect of this EPC being applied (APOA of 1.0) is “just enough time to complete the task when working as quickly as possible,” while an APOA of 0.5 is anchored with “operator must work at a fast pace with reduced time for checking.” It was considered that the time would not be a full effect but more than half effect and was therefore assessed at an APOA of 0.7.

Using the NARA (Ref. E8.1.11) HEP equation yields the following:

$$\text{Crew fails to notice shield plate movement in time} \\ = 0.0004 \times [(20-1) \times 0.1 + 1] \times [(11-1) \times 0.7 + 1] = 0.01 \qquad \text{(Eq. E-3)}$$

Shield Plate Crew Member Fails to Respond to Warnings from Crew—If the crew realized what was happening, they would need to get the attention of the operator in some manner. Their only means of communication is verbal, without the aid of any communication devices. They would need to be heard over the noise of the machinery in the preparation area. The plate control is in direct view of the shield plate, and the operator has roughly 30 to 60 seconds to stop moving the shield plate before a potential direct exposure can occur. If the operator fails to do so, the workers would not have sufficient time to avoid exposure.

The shield plate crew member is on the floor near the platform and is unlikely to be looking up at the workers on the platform, in particular because at this point the shield plate crew member is in the process of opening the shield plate and expects that no one is on the platform. There is machinery noise from the platform and other things in the preparation area like the CTT. The other members of the crew are trying to communicate the error to the shield plate crew member verbally. The action itself (stopping the shield plate) is very simple, and there is plenty of time to execute it once the need is recognized. This error most closely corresponds to the communication error NARA (Ref. E8.1.11) GTT D1, adjusted by the following EPCs:

- GTT D1: Verbal communication of safety-critical data. The baseline HEP is 0.006.

- EPC 4: Low signal-to-noise ratio. This usually pertains to competing data or signals that obscure the most important ones, but it can also mean masking of the important information by other types of distractions. In this case, the masking affect is the abundance of machine noise and the distance between the crew on the platform and the crew member on the floor. The full affect EPC would be ×10, which applies to a required signal being highly masked (such as when there is a proliferation of other signals). Given the level of noise that is expected and the difficulty in communicating above it, it appears reasonable for this task that the APOA be set at 1.0.

Using the NARA (Ref. E8.1.11) HEP equation yields the following:

$$\text{Shield plate crew member fails to respond to warnings from crew} = 0.006 \times [(10-1) \times 1.0 + 1]) = 0.06 \quad \text{(Eq. E-4)}$$

Calculation for Scenario 1(b)—The events in the HEP model for Scenario 1(b) are presented in Table E6.3-5.

Table E6.3-5. HEP Model for HFE Group #3 Scenario 1(b) for 060-OpDPCShield1-HFI-NOW

Designator	Description	Probability
A	Shield plate crew member opens shield plate while crew bolts canister lift fixture.	0.0003
B	Crew fails to notice shield plate movement in time.	0.01
C	Shield plate crew member fails to respond to warnings from crew.	0.06

Source: Original

The Boolean expression for this scenario follows:

$$A \times (B + C) = 0.0003 \times (0.01 + 0.06) = 2E-5 \quad \text{(Eq. E-5)}$$

E6.3.3.4.2.3 HEP for HFE 060-OpDPCShield1-HFI-NOW

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

$$\text{HFE 060-OpDPCShield1-HFI-NOW} = \text{HEP 1(a)} + \text{HEP 1(b)} = 0.0003 + 2E-5 = 0.00032 \sim 0.0004 \quad \text{(Eq. E-6)}$$

E6.3.4 Results of Detailed HRA for HFE Group #3

The final HEPs for the HFEs that required detailed analysis in HFE Group #3 are presented in Table E6.3-6 (with the original preliminary value shown in parentheses).

Table E6.3-6. Summary of HFE Detailed Analysis for HFE Group #3

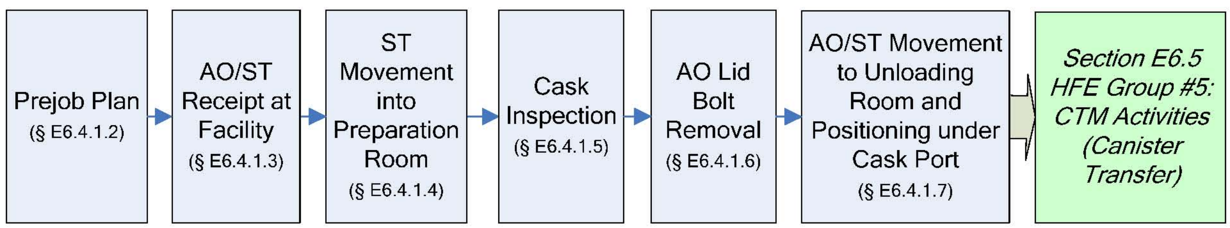
HFE	Description	Final Probability
060-OpDPCShield1-HFI-NOW	Operator fails to properly shield DPC while installing canister lift fixture, leading to direct exposure.	4E−04 (1E−3)

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

Source: Original

E6.4 ANALYSIS OF HUMAN FAILURE EVENT GROUP #4: SITE TRANSPORTER RECEIPT AND MOVEMENT INTO CASK PREPARATION ROOM; AGING OVERPACK PREPARATION AND MOVEMENT TO THE CASK UNLOADING ROOM

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 receipt of an aging overpack and movement into the Cask Unloading Room. The operations covered in this HFE group are shown in Figure E6.4-1. This is the beginning of CRCF operations for an aging overpack/TAD canister. In this operation, a site transporter, carrying an aging overpack, enters the Site Transporter Entrance Vestibule and moves under the preparation platform in the Cask Preparation Room. The aging overpack lid bolts are removed. Once the lid bolts are removed, the crew moves the site transporter with the aging overpack from the Cask Preparation Room to the Cask Unloading Room and positions the cask under the cask port, ready for CTM operations. This operation ends at this point, prior to any CTM activities.



NOTE: § = Section; AO = aging overpack; CTM = canister transfer machine; HFE = human failure event; ST = site transporter.

Source: Original

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

E6.4.1 Group #4 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:

- 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.

E6.4.1.2 Prejob Plan

Before the aging overpack/site transporter reaches the CRCF, a PIC is notified of the type of cask/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 (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 Cask Preparation Room—Loaded Site Transporter Receipt in Site Transporter Vestibule

Two crew members are located at the Site Transporter Entrance Vestibule. When the site transporter approaches the CRCF, one crew member opens the outside overhead door and the other crew member directs the site transporter into the Site Transporter Entrance Vestibule, ensuring there are no vehicles/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 into Cask Preparation Room

Once the site transporter is in the Site Transporter Vestibule, the inside overhead door is opened and the site transporter proceeds to the Cask Preparation Room, in position under the preparation platform, and stops. The inside overhead door is then closed by a crew member, 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 inside door has been closed and the brakes set. The inner and outer doors have an interlock that normally prevents both doors from being opened simultaneously; however, this interlock can be bypassed. The inner door is a shield door.

E6.4.1.5 Cask Inspection

Once the conveyance is parked in the facility, the crew visually inspects and conducts radiological surveys of the exterior of the cask.

[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.

E6.4.1.6 Aging Overpack Lid Bolt Removal

The crew closes the platform shield plate and removes all the cask lid bolts using the cask preparation platform and common tools. Movement of the lid bolts may require the use of the auxiliary crane. Once removed, the bolts are counted and the crew supervisor checks off bolt removal before the site transporter is moved into the Cask Unloading Room.

E6.4.1.7 Aging Overpack/Site Transporter Movement into the Cask Unloading 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 Unloading 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 Cask Unloading Room. There are physical stop points which the site transporter must bump up against to ensure proper alignment. The crew member lowers the site transporter forks, turns off the site transporter and closes the shield door.

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.

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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 Rollover in the Cask Preparation Room*: Operator drives over a significantly uneven surface while moving the ST into the Cask Preparation Room, causing the ST to rollover.	2	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 a site transporter to rollover, 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 CRCF Entry Vestibule/Cask Preparation Room. It is incredible for the site transporter to run over an object large enough necessary to significantly shift its center of mass.
060-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 rollover if the operator continues to operate the ST.	2	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.
060-OpSTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of ST with an SSC while Moving to the Cask Preparation Room*: Operator causes collision of ST with facility structure or equipment while moving through the ST Vestibule to the Cask Preparation Room. The ST is physically unable to over speed, so any collision of the ST is a low-speed collision.	2	3E−03	When the site transporter enters the CRCF it can collide into an SSC, such as the facility door, an auxiliary vehicle or improperly stowed crane rigging. Collision of a site transporter is a similar operation and has the same failure modes as the railcar collision HFE (060-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)
060-OpCTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of Auxiliary Vehicle with ST during Preparation Activities*: While the ST is parked under the Preparation Platform for Preparation activities, the operator of an auxiliary vehicle can collide into the ST. If the speed governor is functioning, this is a low-speed collision.	5	3E−03	In this step the ST is loaded and parked under the cask preparation platform. The speed of auxiliary vehicles is slow, the site transporter is very visible and procedural controls are expected to limit the number of other vehicles in the Cask Preparation Room during cask operations. This HEP was assigned the same preliminary value as railcar collision HFE (060-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) because the dominant mechanism of both failures is collision with an auxiliary vehicle. 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 the site transporter is staged under the platform and the railcar/transfer trailer collision HFE has additional failure modes associated with movement of the site prime mover which are not applicable here. This failure is identical for collision with an auxiliary vehicle during preparation activities in a CTT (060-OpCTCollide1-HFI-NOD; Section E6.3, HFE Group #3).
060-OpFLCollide1-HFI-NOD	*Operator Causes High-Speed Collision of ST with SSC*: Operator can cause an auxiliary vehicle to collide into a loaded ST while the conveyance is parked in the Cask Preparation Room. If the collision is due to the auxiliary vehicle speed governor malfunctioning, then this is a high-speed collision.	5	1.0	The operator can cause an auxiliary vehicle (i.e., forklift) to over speed, resulting in collision with the site transporter while the site transporter is parked under the preparation platform or in transit to or from the platform. In order to accomplish this, the speed governor of the auxiliary vehicle must fail. The site transporter itself is limited by design from going faster than the design speed. To be conservative, unsafe actions that require an equipment failure to cause an initiating event are assigned an HEP of 1.0.
060-OpSpurMove01-HFI-NOD	*Operator Causes Spurious Movement of ST during Preparation Activities*: The ST is supposed to be turned off, with the control pendant stored during this operation. However, if the ST is not in the proper configuration for cask preparation, the operator can inadvertently cause the ST to move. This spurious movement can cause the ST to collide into the preparation platform.	5	1E−04	In this step the site transporter is parked under the preparation platform; the power is off, with the 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 site transporter to be left on, 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 turn off the site transporter, and an operator would have to access the pendent and signal the site transporter to move. This failure is very similar to spurious movement of the CTT during preparation activities (060-OpSpurMove01-HFI-NOD; Section E6.3, HFE Group #3).
060-OpSTCollide2-HFI-NOD	*Operator Causes Low-Speed Collision of ST with an SSC while Moving to the Cask Unloading Room*: Operator causes collision of ST with facility structure or equipment while moving the ST under the platform to the Cask Unloading Room. This is a separate HFE from 060-OpSTCollide1-HFI-NOD because this movement of the ST is temporally separate from ST movement to the Cask Preparation Room. This movement is separated by lid unbolting activities.	6	3E−03	The site transporter can collide into an SSC while in transit from the preparation station to the Cask Unloading Room. This operation is virtually identical to site transporter collision while moving into the Cask Preparation Room (060-OpSTCollide1-HFI-NOD; Section E6.4, HFE Group #4) and was thus given the same preliminary value. While in the same HFE group, this collision was considered a separate HFE from 060-OpSTCollide1-HFI-NOD because this action is temporally separate from site transporter movement to the Cask Preparation Room. This movement is separated by lid unbolting activities.
060-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on ST*: Once the preparation activities are over, an operator turns on the ST, lifts the forks and moves the cask from the Cask Preparation Room to the Cask Unloading Room. There is a shield door between the Cask Preparation Room and the Cask Unloading Room. The operator can impact the cask by inadvertently closing the shield door on the ST as the ST passes through the door.	7	1.0	The site transporter passes through a shield door as it moves from the preparation station into the Cask Unloading Room. During this transfer, the operator can cause the site transporter to collide into the shield door or the operator can close the shield door on the site transporter. See Section E6.0.2.3.3 for a justification of this preliminary value.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
060-OpLoadDrop-HFI-NOD	*Operator Causes ST to Drop 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 or during preparation activities.	2	N/A	There are no crane operations in this step, so the only way for an aging overpack to be dropped is if it falls off the site transporter. The site transporter is like a fork lift, which holds the aging overpack several inches above the ground while in transit. The site transporter cannot lift the aging overpack greater than one foot, so a drop greater than a foot is not plausible in this step. The aging overpack is prevented from moving on or falling off the site transporter by a securing mechanism which locks the aging overpack into place. The site transporter has traveled from the aging pad to the facility. It is highly unlikely that the aging overpack can drop in the facility due to human error, given it has not dropped in transit to the facility. Also, there are interlocks which prevent the site transporter from moving if the aging overpack is not properly secured. Therefore, drop of an aging overpack due to human failure was omitted from analysis.
060-OpAOImpact01-HFI-NOW	*Operator Causes AO Impact during Cask Preparation Activities*: While unbolting the AO lid, the operator may use the auxiliary crane to remove the bolts. If this occurs, the operator can potentially impact the cask if the crane is moved with the hook lowered below the platform.	5	3E−03	In this step the site transporter is stationed under the Preparation Station and the lid bolts are removed, with the aid of the auxiliary crane. 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 (containing an aging overpack) 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. The likelihood of impacting a cask was assessed to be comparable to the crane impact during upending and removal HFE (060-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2: Cask Upending and Removal from Conveyance) and was accordingly assigned the same preliminary value. This failure is “highly unlikely” (one in a thousand or 0.001) but is adjusted because there are several ways for an impact to occur (×3). This is considered a particularly conservative assessment because, in comparison with upending and removal, there are fewer crane movements in this operation, and there is a platform around the site transporter which makes it harder to impact the site transporter.
060-OpTipOver003-HFI-NOD	*Operator Causes Tipover of ST*: If the operator improperly stows the crane rigging during or after preparation activities, it can catch the ST or cask. If the crane becomes attached to the ST or cask and the operator continues to move the ST or crane, the ST could tip over.	5	1E−04	In this step the site transporter is moved from the site transporter entrance vestibule to the preparation station, the lid bolts are removed, and the site transporter is moved to the Cask Unloading Room. In order to get a tipover of the site transporter, the crane must be attached to the aging overpack or site transporter and the crane or site transporter must also move. At no point in the preparation activities is the crane attached to the aging overpack. The lid bolts may be removed with the aid of the auxiliary crane. Therefore, the only way for the crane to be attached to the cask is if the crane rigging catches the cask or site transporter, probably while moving to or away from the platform. This is unlikely because the site transporter is protected by the platform and shield plate during most of this operation. If the rigging is caught during preparation activities, it is unlikely that the crane operator won’t notice while moving the crane. It is also unlikely that, when the site transporter is moving to or from the preparation platform, the site transporter operator and observers won’t notice that the rigging has caught the site transporter because a tipover is a slow process. This operation was given the same preliminary value as the cask tipover during upending and removal HFE (060-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2: Cask Upending and Removal from Conveyance) because it has the same dominant failure mode. The crane rigging is improperly stowed and the crew fails to notice before the cask is tipped over. 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.
060-OpTipOver3-HFI-NOD	*Operator Causes Tipover of ST during Movement to the Cask Unloading Room*: The operator can improperly stow the crane rigging and it can catch the ST or AO. If this happens while the ST is moving to the unloading room it can cause the ST to tip over.	6	N/A	The ST, loaded with an AO, undergoes a set of operations which includes operations under the preparation platform and then movement of the ST away from the platform. A tipover of the 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 ST away from the platform. The event sequences, however, model a tipover during platform activities and a tipover during ST movement. Because this is only one human failure, the appropriate preliminary value was only modeled in the event sequence associated with platform activities (060-OpTipover003-HFI-NOD above, modeled in ESD 5). The HEP for a tipover in the event sequence associated with the subsequent movement of the ST (060-OpTipOver3-HFI-NOD in ESD 6) was assigned a probability of zero to avoid double counting.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
060-OpImpact0000-HFI-NOD	*Operator Causes Impact of Cask during Transfer from Cask Preparation Room to the Cask Unloading Room*: While moving from the Cask Preparation Room to the Cask Unloading Room, the ST can impact the crane hook or rigging if it is improperly stowed.	6	N/A	While moving from the preparation station to the Cask Unloading Room, the site transporter can impact the crane hook or rigging if it is improperly stowed. The shield plate is closed through the entire set of aging overpack preparation activities. It is unlikely, then, that the crane rigging can be improperly stowed to cause an impact to the site transporter while it is moving to the Cask Unloading Room. It is more likely that rigging can be improperly stored before preparation activities begin and before the site transporter is under the protection of the platform and shield plate. Therefore, any crane interference with the site transporter is already covered by 060-OpAOImpact01-HFI-NOW (Operator Causes Impact between Site Transporter and SSC during Cask Preparation) and 060-OpTipover003-HFI-NOD (Operator Causes Tipover of Site Transporter).
Drop of Object on AO	*During AO Preparation Activities the AO Lid Is Unbolted*: If the lid bolts are removed with the crane, it is possible that they can be dropped onto the cask.	N/A	N/A [a]	Aging overpack preparation activities simply entail removing the lid bolts. In this step the lid bolts or the tools used to remove the lid bolts can be dropped onto the aging overpack. This failure was omitted from analysis because the bolts and tools were not considered to be "heavy objects."
060-Liddisplace1-HFI-NOD	*Operator Inadvertently Displaces Lid*: During preparation activities the operator can improperly store the crane rigging such that it catches the lid lift fixture and pulls off the AO lid, resulting in a direct exposure.	17	N/A	In this step the lid is unbolted. Due to design changes to the preparation platform, improperly stowed rigging during this operation won't 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.

NOTE: [a] Historical data was used to produce a probability for this HFE. This probability is not covered as part of the HRA, but rather addressed in Attachment C on active component reliability data.

AO= aging overpack; CRCF = Canister Receipt and Closure Facility; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; N/A = not applicable; SNF = spent nuclear fuel; SSC = structure, system, or component; ST = site transporter.

Source: Original

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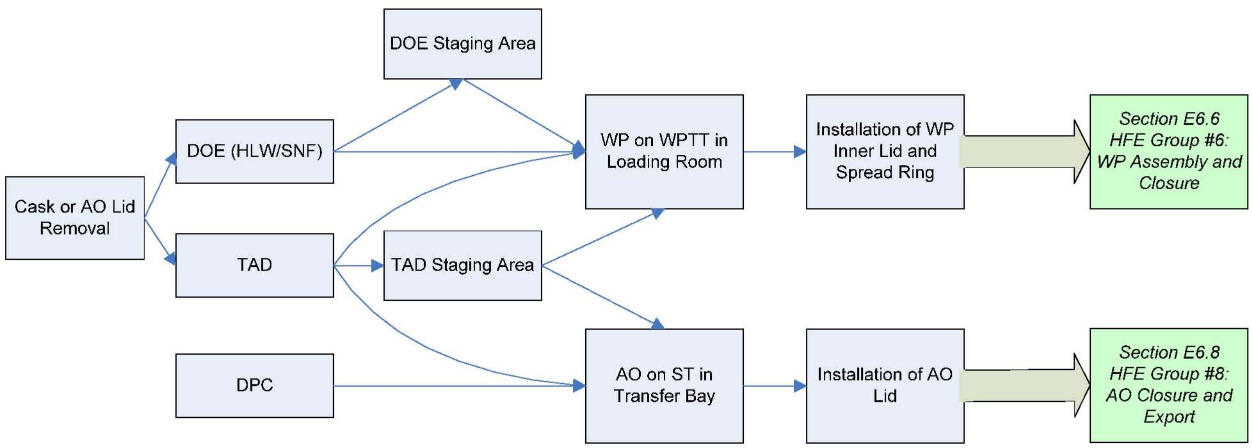
E6.4.3 Detailed Analysis

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 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: CTM ACTIVITIES: TRANSFER OF A CANISTER INTO OR OUT OF STORAGE, A TRANSPORTATION CASK, A WASTE PACKAGE, OR AN AGING OVERPACK WITH THE CTM

HFE group #5 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering CTM operations. The overall process associated with these operations is graphically depicted in Figure E6.5-1, which shows how various waste forms are moved by the CTM from their transportation cask to their intermediate and final destinations.

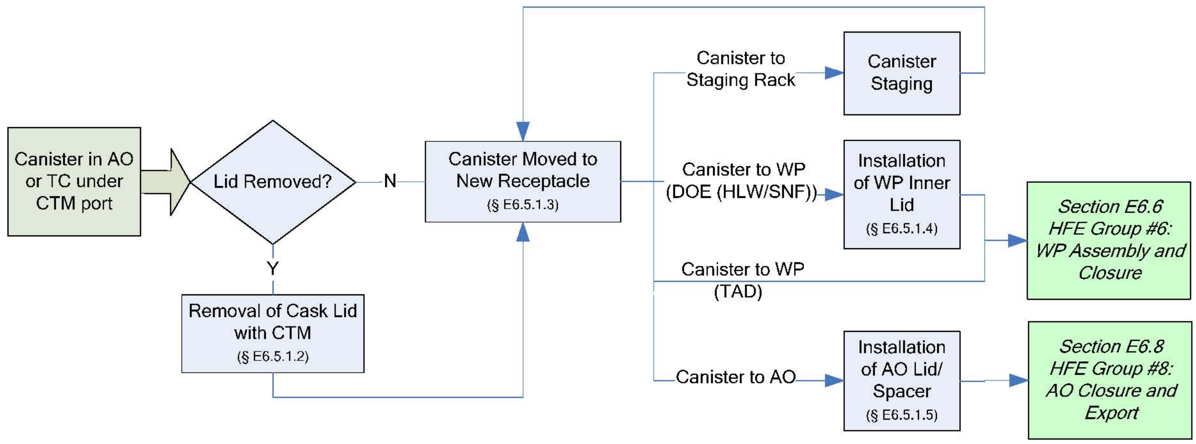


NOTE: § = section; AO = aging overpack; DPC = dual-purpose canister; DOE = U.S. Department of Energy; HFE = human failure event; HLW = high-level radioactive waste; SNF = spent nuclear fuel; ST = site transporter; TAD = transportation, aging, and disposal (canister); WP = waste package; WPTT = waste package transfer trolley.

Source: Original

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

The activities covered in HFE group #5, which accomplish the transfers shown in Figure E6.5-1, are shown in Figure E6.5-2. The activities covered in this HFE group begin with a canister in position aligned with a port. The canister could be in a transportation cask, in an aging overpack, or in the staging area. Transportation casks containing TAD canisters and DOE SNF have their lids unbolted, ready for removal and storage by the CTM. Transportation casks containing DPCs have their lids already removed; there are no lids associated with the staging rack. CTM activities include preparing the CTM (attaching grapple and aligning CTM to port), removing the cask lid (if required), removing the canister from the old receptacle, and moving the canister to the appropriate receptacle. Depending on where the canister came from and where it is headed, the appropriate receptacle could be a waste package, an aging overpack, or the staging area. This operation ends when the canister has been placed in its intended location, the CTM has been withdrawn, and the port gate has been closed.



NOTE: § = section; AO = aging overpack; CTM = canister transfer machine; DOE = U.S. Department of Energy; HFE = human failure event; HLW = high-level radioactive waste; SNF = spent nuclear fuel; TAD = transportation, aging, and disposal (canister); TC = transportation cask; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

Figure E6.5-2. CTM Operations Process Flow

E6.5.1 Group #5 Base Case Scenario

There are nine variations with three waste package loading possibilities for the Group #5 base case scenario:

1. Move TAD canister from aging overpack or transportation cask to waste package
2. Move TAD canister from aging overpack or transportation cask to TAD staging area
3. Move TAD canister from staging area to waste package
4. Move TAD canister from transportation cask to aging overpack
5. Move TAD canister from staging area to aging overpack
6. Move DOE (HLW/SNF) canister from transportation cask to DOE staging area
7. Move DOE (HLW/SNF) canister from transportation cask to waste package
8. Move DOE (HLW/SNF) canister from staging area to waste package
9. Move DPC to aging overpack.

Waste package loading configurations:

1. Waste package with one TAD
2. Waste package with one DOE SNF canister and four or five HLW canisters
3. Waste package with two HLW canisters and two DOE SNF canisters (multicanister overpacks)

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. From transportation cask/aging overpack—The transportation cask is secure in the CTT or the aging overpack is secure in the site transporter; the transportation cask or aging overpack is in position, aligned under the cask port in the Cask Unloading Room. For non-DPCs, the lid is sitting on the transportation cask or aging overpack, unbolted. The transportation cask and aging overpack have a lid lift fixture attached. For a DPC, the cask lid is removed.

2. From staging—The TAD or DOE canister is sitting in the TAD and DOE staging area, and the door to the staging area is closed.

3. Transfer to aging overpack or waste package—The aging overpack or waste package is stationed under the aging overpack or waste package port, secured, with the lid removed. The waste package is in a WPTT and has a waste package shield ring in place.

4. CTM operations are performed remotely from a control room unless otherwise specified.

5. The CTM has the following safety features and hardwired interlocks:

   A. Vertical movement and upper limit—The CTM is raised and lowered with the use of an adjustable speed drive (ASD). The ASD has at least three settings: one for lift of canisters, one for lift of objects that do not fit inside the bell (e.g., cask lid), and a maintenance mode. The operator selects the setting and uses the controller to raise the hoist until it automatically stops at the selected setting height.

      1) For the canister mode, the ASD automatically stops once the canister clears the bottom of the bell. There is also an optical sensor at the bottom of the bell that, once cleared, stops the hoist and erases the lift command (i.e., can only lower the hoist).

      2) For the object mode, the ASD automatically stops the hoist once it clears the port gate. The operator can potentially restart the lift operation and further lift the object.

      3) The maintenance mode is fully manual; the ASD does not stop the lift. The optical sensor interlock itself is not to be bypassed; rather, the bell is uncoupled from the trolley, effectively bypassing this interlock. Once the bell and trolley are coupled, the sensor bypass is in effect.

      Above the ASD stop point is an upper limit switch that, when reached, stops the hoist from lifting. This first limit switch (final hoist lower limit) effectively erases the lift command. The hoist still has power, but the operator can only lower the hoist. Roughly a foot above that limit switch is another limit switch (i.e., the final hoist upper limit) that, when reached, cuts off the power to the CTM hoist.

B. Horizontal movement and port alignment—There is a visually based system that aligns the CTM with the canister such that the grapple can properly engage the canister. The form of this system may use a scheme as simple as laser/target alignment or a more complex system including image recognition software coupled with PLCs. Likewise, horizontal movement and final alignment of the CTM with the cask, waste package, and staging ports is potentially a highly automated process. However, to be conservative, the manual horizontal movement process is analyzed here, generically relying on a visual alignment system and camera for alignment confirmation.

C. There is an interlock between the shield skirt and the port gate that requires the shield skirt to be lowered in order for the port gate to open. If the automated system is used, the CTM alignment is based on a coordinate system, and the CTM would not be able to move at all if the port gate is open. However, if the process is manual, to get exact alignment, the CTM needs a "jog" feature that allows the CTM to move in small increments while the shield skirt is lowered. There is also a maintenance bypass for this interlock.

D. There is an interlock between the CTM bridge and trolley travel and the shield skirt position. Neither the CTM bridge nor the trolley can travel while the skirt is lowered.

E. There is an interlock between the slide gate and shield skirt; the shield skirt cannot be raised unless the slide gate is closed. This interlock can be bypassed for maintenance.

F. There are interlocks preventing improper hoist movement. The hoist cannot move unless the shield skirt is lowered. This interlock is based on hoist movement, not position, so movement with the hoist too low is not precluded.

G. There are speed limiters designed into the motors.

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

I. There are anti-collision interlocks on the CTMs for the CRCF.

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

K. There is an interlock that prevents CTM canister grapple (primary grapple) operation if the grapple is not properly connected to the hoist.

L. There is an interlock between the grapple engagement/position (fully engaged or fully disengaged) and hoist movement. The secondary grapple has the same interlock that is enabled when the power is connected to the grapple.

M. The CTM is mechanically or electrically prevented from inadvertent canister disengagement.

N. The following grapples are associated with these CTM activities:

1) Lid grapple (for transportation cask, aging overpack, and waste package lids)

2) Shield plug grapple (for waste package shield plug and spread ring)

3) DOE canister grapple (there are multiple types of DOE canister grapples, and the proper grapple depends on where the HLW/SNF came from)

4) DPC canister and TAD canister grapple—The DPC lift adapter matches the TAD canister lifting feature interface.

O. It is expected that if the wrong grapple is used, the grapple designs preclude partial or full engagement (i.e., the wrong grapple would be too big, too small, or otherwise mechanically incompatible with the fixture)

P. Grapple installation—When the design is finalized, one option under consideration is that an automatic system would be used to remove and attach the grapples. It is expected that such a system would be more reliable than a local manual process. This analysis retains the local manual process so that compliance can be demonstrated without the automatic system.

6. The shield door is closed. There is an interlock between the port slide gates and the shield doors; the port slide gate cannot be open while the shield doors are also open.

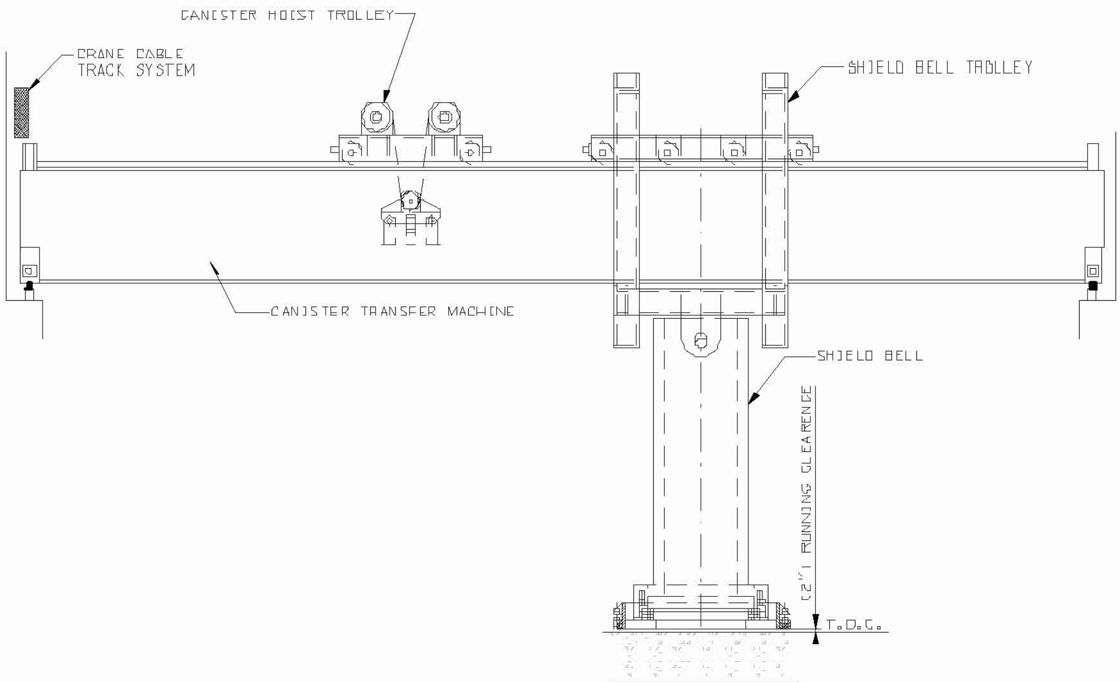
7. There are interlocks between the waste package port slide gate and the WPTT. The gate cannot open unless the WPTT is properly aligned under the port and the waste package shield ring is in place. The power to the WPTT is removed when the waste package port gate is open; it reenergizes when the gate closes.

The following personnel are involved in this set of operations:

- CTM operator
- Crew members (two people)
- Supervisor.

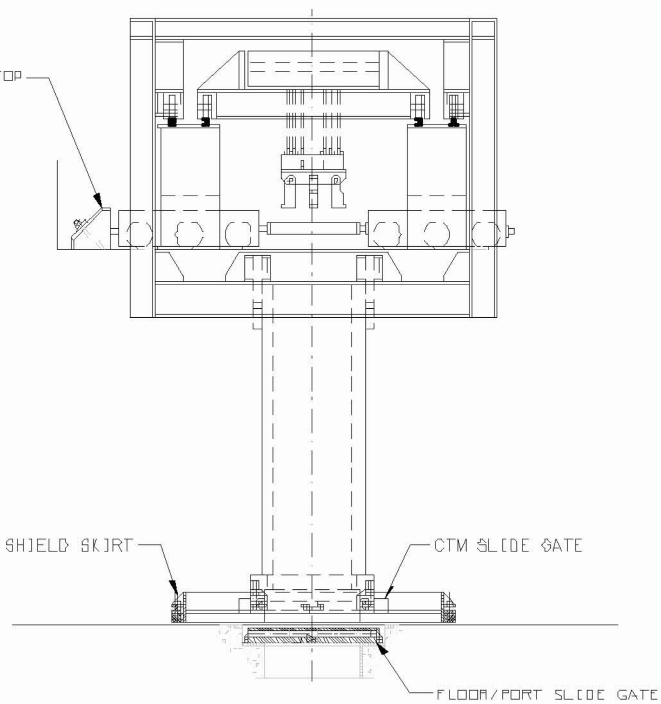
Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel.

Figure E6.5-3 and Figure E6.5-4 are simple diagrams illustrating the CTM.



Source: Modified from CRCF, IHF, RF, and WHF Canister Transfer Machine Mechanical Equipment Envelope (Ref. E8.1.6)

Figure E6.5-3. Canister Transfer Machine—Side View



Source: Modified from CRCF, IHF, RF, and WHF Canister Transfer Machine Mechanical Equipment Envelope (Ref. E8.1.6)

Figure E6.5-4. Canister Transfer Machine—End View

E6.5.1.2 Removal of Transportation Cask or Aging Overpack Lid with CTM (for TAD Canister or DOE SNF)

Proper Grapple Installation—The CTM operator moves the CTM to the CTM maintenance area (Canister Transfer Room floor), where a crew member manually takes off and stores the grapple attached to the CTM (i.e., canister grapple) and replaces it with the lid grapple. The CTM operator also ensures that the ASD is set to the appropriate setting to lift the canister.

Moving CTM to Cask Port—The CTM operator uses a visual alignment system and a camera to position the CTM, with the lid grapple, over the cask port (or staging area). There is a position indicator, along with a camera view, so the operator knows when the CTM is in position.

Opening CTM Slide Gate and Port Slide Gate—The CTM operator remotely lowers the skirt shield, opens the CTM slide gate, and opens the cask port or TAD canister and DOE staging area slide gate once the CTM is in place.

Lifting Cask (Transportation Cask or Aging Overpack) Lid into CTM and Slide Gate Closure—The operator first sets the ASD to lid lift mode and then lowers and engages the lid grapple; the grapple does not lower unless the slide gate is open and skirt is lowered. Grapple engagement is manual and is verified visually via camera and via an indicator. Once the grapple is engaged and verified, the operator then lifts the cask lid up to the bottom of the CTM bell just past the CTM slide gate. At this point the operator closes the port and CTM slide gates.

Moving CTM to Transportation Cask or Aging Overpack Lid Station and Lowering Lid to Lid Station—The CTM operator lifts the CTM skirt and moves the CTM with lid to the lid station. Once at the lid station, the operator lowers the lid, disengages the grapple, lifts the grapple, resets the ASD to canister lift setting, closes the slide gate, and lifts the skirt. A camera is used to ensure that the lid is staged in the proper location. Once the lid is removed, the lid lift grapple is replaced with the proper canister lifting grapple as described in step 1. The CTM is positioned above the correct port for removal of the canister.

E6.5.1.3 Move Canister to New Receptacle (All Variations)

Proper Grapple Installation—The CTM operator moves the CTM to the CTM maintenance area (Canister Transfer Room floor), where a crew member manually takes off and stores the grapple attached to the CTM (either a lid grapple or canister grapple) and replace it with the appropriate canister grapple (i.e., a DPC grapple, a TAD canister grapple, or one of five DOE grapples). The CTM operator also ensures that the ASD is set to the appropriate setting to lift the canister.

Moving CTM to Cask Port—The CTM operator uses a visual alignment system and camera to position the CTM, with lid grapple, over the cask port (or staging area). There is a position indicator, along with a camera view, so the operator knows when the CTM is in position. Once in position, the CTM operator then lowers the shield skirt.

Opening CTM Slide Gate and Port Slide Gate—Once the CTM is in position over the cask or staging location port, with the shield skirt lowered, the CTM operator remotely opens the CTM slide gate and the cask port slide gate.

Lifting Canister into CTM—The CTM operator again looks at the relative canister and hoist position and adjusts the alignment if necessary to ensure that the CTM is over the canister (some casks have several canisters). This final adjustment is done with the alignment system, in conjunction with a camera view. Once the CTM is appropriately aligned to the canister, the operator lowers the canister grapple and engages the grapple. Grapple engagement is automatic, but it is verified visually via camera and an indicator. The operator then lifts the canister by holding down a controller (i.e., joystick) until the ASD automatically stops the lift.

Closing CTM Slide Gate and Port Slide Gate—Once the canister is raised inside the bell, the operator closes the CTM slide gate, closes the port slide gate, and lifts the CTM skirt in preparation for movement.

Moving CTM to Destination Port—The CTM operator moves the CTM from the cask port into position over the waste package or aging overpack port or over the TAD and DOE staging area using a visual alignment system in conjunction with a camera view to ensure alignment with the port. Once positioned, the operator lowers the skirt of the CTM.

Opening CTM Slide Gate and Port Slide Gate—The CTM operator then opens the CTM slide gate and the waste package port, aging overpack port, or TAD canister and DOE staging area slide gate.

Lowering Canister—Once the port gate is open, the operator verifies alignment using a visual alignment system in conjunction with a camera view; if the canister is not properly aligned, the CTM operator makes fine adjustments of the CTM position until alignment is verified. The operator then lowers the canister into position in the waste package port, aging overpack port, or storage area (the TAD canister has two staging positions, and the DOE canister has 10 staging positions); disengages the grapple; verifies disengagement (via camera and indicator); and then retracts the grapple.

*Variation on grapple disengagement: To disengage the DOE grapple, the operator must set the load down, lift it up, and set it back down.

Closing CTM Slide Gate and Port Slide Gate—Once the grapple is raised, the operator closes the CTM Slide Gate; closes the waste package port, aging overpack port, or TAD canister and DOE staging area slide gate; and lifts the CTM skirt in preparation for movement.

E6.5.1.4 Preparing Waste Package for Closure

For unshielded canisters that were transferred to waste packages for export, the following steps are applicable (Note: This step is not applicable to TAD canisters in a waste package; they are moved directly to the Waste Package Closure Room without further preparation):

Grapple Exchange—The CTM operator moves the CTM to the CTM maintenance area, where a crew member manually removes the canister grapple and attaches the inner lid grapple. At this point, the CTM operator sets the ASD to the proper setting for lifting the waste package inner lid (shield plug with spread ring). The operator then closes the slide gate and lifts the skirt.

Moving CTM to Waste Package Inner Lid Station—Once the skirt is lifted, the operator remotely moves the empty CTM and positions it over the waste package inner lid station, lowers the skirt, and opens the CTM slide gate.

Lifting the Waste Package Inner Lid into the CTM—Once the CTM is positioned, the operator then lowers the grapple, engages the grapple, verifies the grapple engagement via camera and indicator, and lifts the waste package inner lid into the CTM. The CTM operator then closes the CTM slide gate and lifts the skirt. Quality assurance verifies this step.

Moving Waste Package Inner Lid to Waste Package—The operator remotely moves the CTM and positions it over the waste package. To do this, the operator uses a visual alignment system in conjunction with a camera view to ensure alignment with the center of the port.

Opening Waste Package Port Slide Gate, Placing Waste Package Inner Lid in Waste Package, and Closing Waste Package Slide Gate—The CTM operator lowers the skirt, opens the waste package port slide gate, opens the CTM slide gate, and lowers the inner lid into position. Once in position the operator disengages the grapple, verifies full disengagement (via camera and indicator), retracts the grapple, and then closes the waste package and CTM slide gates.

E6.5.1.5 Preparing Aging Overpack to Leave Cask Unloading Room

For canisters that were transferred to aging overpacks for export, the following steps are applicable:

Grapple Exchange—The CTM operator moves the CTM to the CTM maintenance area, where a crew member removes the canister grapple and attaches the lid grapple. The operator then closes the slide gate and lifts the skirt. The CTM operator also sets the ASD to the proper setting for moving the aging overpack lid.

Install Aging Overpack Spacer (if required)—Once the skirt is lifted, the CTM operator retrieves the aging overpack spacer, moves the CTM to the aging overpack, lowers the shield shirt, opens the port and CTM slide gates, and lowers the hoist. Once the spacer is in place, the CTM operator disengages the grapple, retracts the hoist, closes the CTM port and slide gates, and lifts the shield skirt for movement.

Moving CTM to Aging Overpack Lid Station and Retrieving Lid—Once the skirt is lifted, the operator moves the CTM and positions it over the aging overpack lid station. The operator then lowers the grapple, engages the grapple, verifies the engagement (via camera and indicator), and lifts the aging overpack lid.

Moving CTM to Cask Port—The CTM operator positions the CTM, with lid, over the aging overpack cask port and lowers the skirt. The operator uses a visual alignment system in conjunction with a camera view to ensure alignment with the port.

Opening Cask Port Slide Gate and Placing Lid on Aging Overpack—Once the skirt is lowered, the operator remotely opens the cask port slide gate, confirms alignment (via the visual alignment system and camera), and lowers the lid into position. The CTM operator then disengages the grapple, verifies that the grapple is disengaged (via indicator and camera), and retracts the grapple.

Closing Cask Port Slide Gate—Once the grapple is retracted, the operator remotely closes the cask port slide gate.

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 canister transfer with the CTM 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 III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.