Operator Fails to Notice Grapple Not Fully Engaged through Camera—As the lift begins, the operator is supposed to watch through the cameras. This provides the opportunity to note that the grapple is not properly engaged (e.g., unexpected lid movement to one side or tilting of the grapple). This also gives the operator the opportunity to question the stability of the connection and to lower the lid back down to recheck the connection. However, the operator is not expecting any problems in this simple operation, and the tendency is to believe that any perceived problems are illusions caused by the distortions of viewing through a camera.

In this task, the operator is checking the operator's own actions, again through the camera. The operator believes that the action was initially performed correctly (because the action was performed by the operator), and this belief is confirmed by a false positive indication from the interlock, so this last observation is deemed completely dependent on the prior actions. Using THERP (Ref. E8.1.26, Table 20-21) to assess dependency, item (5) for complete dependency:

Operator fails to notice grapple not fully engaged through camera = 1.0

Lid Drops from Grapple and Strikes Canister—Just because the lift is occurring with an incomplete engagement of the grapple does not mean that the grapple falls. The safety margin built into these systems means that it is possible that the lift and placement can be completed successfully even with improper installation, especially given that it is sized for a canister, and the lid is much lighter. Additionally, even if the lid does fall, it could fall early (a weak connection) or later (sufficient connection that they need time and motion to cause them to break loose). These two cases can result in the lid breaking loose when it is not above the canister. In addition, it is not a certainty that the lid, once dropped, falls in an orientation that impacts the canister in the transportation cask or aging overpack even if it is above the canister at the time of the drop (the orientation of the falling lid may cause it to only impact the transportation cask or aging overpack structure).

This event is quantified in Section E6.4.3.4.1.

Lid drops from grapple = 0.05

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

Table E6.4-5. HEP Model for HFE Group #4 Scenario 1(b) for 200-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	Operator fails to fully engage grapple	0.07
B	Grapple engagement interlock gives false positive signal	2.7E−5
C	Operator fails to notice grapple not fully engaged through camera	1.0
D	Lid drops from grapple and strikes canister	0.05

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

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C \times D = 0.07 \times 2.7E{-5} \times 1.0 \times 0.05 = 1E{-7} \qquad \text{(Eq. E-11)}$$

E6.4.3.4.2.3 HFE Group #4 Scenario 1(c) for 200-OpCTMdrop001-HFI-COD

1. Operator leaves ASD in maintenance mode OR operator places ASD in canister mode OR ASD height control fails.

2. Operator fails to notice lift is taking too long OR operator "locks" lift button into position.

3. Load cell overload interlock fails.

4. Mechanical failure of hoist under overload causes lid drop.

Operator Leaves ASD in Maintenance Mode—The ASD controls the height of the lift. Before beginning the lifting process, the operator should ensure that the ASD is in the lid lift mode. It could be in maintenance mode because of activities performed in the days between canister transfers. It is not clear how often this would occur, so for the purpose of this analysis, the bounding case is that the ASD is always in maintenance mode between canister transfers. Therefore, the operator must change the mode prior to the lid lift. In doing this, the operator could either fail to change the mode (miss this step in the process) or erroneously place it in the canister lift mode (the next action discussed provides further information), either of which results in the ASD trying to lift the lid too high and impacting the bottom of the bell. The third way this could occur is simply a mechanical failure of the height control set point of the ASD, which is discussed separately below.

The CTM operator is supposed to set the CTM system to the appropriate lift mode prior to performing a lift. This is fundamental to the operation, not simply a step in a procedure that can be missed. The initial action to set the mode is quite simple, so the only realistic way that the operator can leave the ASD in maintenance mode is to completely fail to take any actions to set the CTM system for a lift. This failure can be represented by NARA GTT B3, adjusted by the following EPCs:

- GTT B3: Set system status as part of routine operations using strict administratively controlled procedures. The baseline HEP is 0.0007.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The baseline HEP is used without adjustment.

Operator leaves ASD in maintenance mode = 0.0007

Operator Places ASD in Canister Lift Mode—Given that the CTM operator has correctly decided to set the CTM system status prior to operations, the appropriate operating mode also needs to be selected. There are only two modes to choose from: lid lift and canister lift. The ASD control is a screen where the operator can scroll between the choices to pick the appropriate lift mode. The act of selecting the wrong mode from these two can be best represented by task execution error NARA GTT A1, adjusted by the following EPCs:

- NARA 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.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The ASD control system requests confirmation from the operator (e.g., "You have selected canister lift. Confirm Y/N"). The baseline HEP is used without adjustment.

Operator places ASD in canister lift mode = 0.005

ASD Height Control Fails—This is a mechanical failure of the ASD controller. This event is quantified in Section E6.4.3.4.1.

ASD height control fails = 3.4E−5

Operator Fails to Notice Lift Is Taking Too Long—Lifting the lid takes on the order of a few minutes, whereas lifting the canister takes on the order of ten minutes. Because the operator has to hold the lift button or the lift stops, there is an opportunity to notice that the hoist has not stopped when expected and to release the button and stop the hoist, either before the lid contacts the interior of the bell or before it begins to overload the system. Realistically, the operator would have on the order of 30 seconds between when it should stop and when it would be too late. The hoist position indicator and camera view are in front of the operator on the control panel.

The operator is supposed to hold the lift button until the lift automatically stops. The operation has been performed many times in the past by the operator, and the operator has an instinctive feel for how long the lift should take. If the operator feels it is taking too long, the operator need only look at the camera and the indicators on the control panel for verification. Failing to recognize this situation can be represented by CREAM CFF I3, adjusted by the following CPCs with values not equal to 1.0:

- CFF I3: Delayed interpretation (not made in time). The baseline HEP is 0.01.

- CPC "Working Conditions": The operator has optimal working conditions in the RF Control Room. The CPC for an interpretation task with advantageous working conditions is 0.8.

Applying these factors yields the following:

Operator fails to notice lift is taking too long = 0.01 × 0.8 = 0.008

Operator "Locks" Lift Button into Position—Another way that the lift would go too long is if the operator were to use some inventive means to "lock" the button in place. The CTM lifts are a tedious task and require holding the button in place for long periods of time. There is no locking feature associated with the ASD that would keep the button in place; however, it is not inconceivable that, after many lifts have been done without an ASD failure, an operator would develop a creative technique to accomplish this. Since the operator develops trust in the ASD and the other system interlocks, the operator would not believe that the deviation is unsafe, and it would free up time to prepare for subsequent steps or to perform other duties.

The operator is supposed to hold the lift button until the lift automatically stops. However, it is always possible to rig something up that would hold the button in place, relieving the operator of the "inconvenience" of having to hold it down. The HRA team believes that the preferred methods do not provide baseline HEPs for such unsafe actions. Therefore, the ATHEANA expert judgment approach is used. In considering the judgment, HEART and NARA do provide some insight into the existence of EPCs that can affect this unsafe action, such as the following:

- A mismatch between an operator's model of the world and that imagined by a designer—The designer considers the "push and hold" as a safety feature that keeps the operator's attention on the operation. The operator considers it as an unnecessary inconvenience in what should be an automated function.

- A mismatch between real and perceived risk—Locking the button removes a layer of safety provided by the operator monitoring operations, but the operator perceives the reliability of the limits and interlocks as such that there is no additional risk involved (HEART EPC 12).

- Little or no independent checking or testing of output—A single operator is operating the CTM from a remote location. No one is looking over the operator's shoulder (HEART EPC 17).

- An incentive to use other, more dangerous procedures—Holding the button means that the operator's ability to accomplish other work is limited. The operator can be more efficient (e.g., planning for future activities, completing paperwork) by trusting the control system to complete the task (HEART EPC 21, NARA EPC 15).

- Operator underload, boredom—Holding a button when one fully expects that the system automatically controls the operation is not very challenging (NARA EPC 13).

- Little or no intrinsic meaning in a task—The operator really has to wonder why the system wasn't designed to simply perform the operation on its own. The operator could come to consider the "push and hold" feature as a poorly thought-out design flaw (HEART EPC 28).

Taking this as a whole, the HRA team judges that the operator locks the button in place about 10% of the time (which can be interpreted as some operators doing it quite frequently and other operators less or not at all, depending on their compunction to do so). However, this action is not unrelated to prior failures in this scenario. An operator who fails to set the CTM system status (leaves the ASD in maintenance mode) has already demonstrated a predilection towards rushing and perhaps a bias towards shortcuts for the particular lift. Therefore, the HRA team judges that the success or failure of this task is related to the way in which the ASD failure occurs. It is judged that if the failure occurs as a result of leaving the ASD in maintenance mode, the HEP for locking the button in place is twice the baseline (0.2). If it occurs for either of the other two reasons, the HEP is one-half the baseline (0.05).

Operator "locks" lift button into place (ASD left in maintenance) = 0.2

Operator "locks" lift button into place
(ASD placed in canister mode or fails mechanically) = 0.05

Load Cell Overload Interlock Fails—The load cell has an interlock that shuts off the hoist if it senses that the load exceeds the approved load for the hoist. The hoist straining to lift the lid in contact with the bell (which would put the full load of the bell on the hoist) would be one such condition. Since this would shut the hoist down prior to exceeding the ultimate capacity of the system, it would have to fail in order to cause a drop.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell interlock fails = 2.7E−5

Mechanical Failure of Hoist Under Overload Causes Lid Drop—There are three potential failure modes that could cause the lid to detach from the hoist. The cable could fail, the grapple could break free from the lower block, or the lifting fixture could break free from the grapple or lid. However, just because the hoist keeps pulling does not mean that the lid falls (the hoist motor could overload and fail before the lid becomes detached from the hoist) or that the lid, once dropped, falls in an orientation that can impact the canister in the transportation cask or aging overpack (the orientation of the falling lid may cause it to only impact the transportation cask or aging overpack structure).

This event is quantified in Section E6.4.3.4.1.

Mechanical failure of hoist under overload causes lid drop = 0.1

HEP Calculation for Scenario 1(c)—The events in the HEP model for Scenario 1(c) are presented in Table E6.4-6.

Table E6.4-6. HEP Model for HFE Group #4 Scenario 1(c) for 200-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	Operator leaves ASD in maintenance mode	0.0007
B	Operator places ASD in canister mode	0.005
C	ASD height control fails	3.4E−5
D	Operator fails to notice lift is taking too long	0.008
E1	Operator “locks” lift button into position (ASD left in maintenance)	0.2
E2	Operator “locks” lift button into position (ASD placed in canister mode or fails mechanically)	0.05
F	Load cell overload interlock fails	2.7E−5
G	Mechanical failure of hoist under overload causes lid drop	0.1

NOTE: ASD = adjustable speed drive; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$\{A\times (D + E1) + [(B + C) \times (D + E2)]\}\times F \times G = \{0.0007 \times (0.008 + 0.2) + [(0.005 + 3.4E{-}5) \times (0.008 + 0.05)]\} \times 2.7E{-}5 \times 0.1 = (< 1E{-}8) \qquad \text{(Eq. E-12)}$$

E6.4.3.4.2.4 HFE Group #4 Scenario 1(d) for 200-OpCTMdrop001-HFI-NOD

1. CTT is not sufficiently centered under port.
2. Operator fails to notice CTT not sufficiently centered.
3. Operator fails to notice lid tilt and continues lift OR operator “locks” lift button into position.
4. Lid catches and jams in port.
5. Load cell overload interlock fails.
6. Mechanical failure of hoist under overload causes lid drop.

CTT Is Not Sufficiently Centered under Port—This unsafe action actually occurs prior to this operation, during movement of the CTT into the Cask Unloading Room. The CTT operator brings the unit into the Cask Unloading Room and centers it directly under the cask port by aligning it against end stops that properly locate it and by using markings on the floor. If the cask is not properly centered, it is possible that the lid could strike the ceiling around the cask port rather than rising smoothly through the cask port. The cask would have to be off-center by more than a foot.

The unsafe action results from stopping the CTT prematurely and leaving it at least a foot short of the proper location. This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

- CFF E1: Execution of wrong type performed (with regard to force, distance, speed, or direction). The baseline HEP is 0.003.
- CPC "Available Time": There is adequate time to perform this task. The only time pressure is the desire to keep the process moving, but the consequences are insignificant. The CPC for an execution task with adequate time is 0.5.
- CPC "Adequacy of Training/Preparation": This routine task is well trained and practiced and performed quite frequently. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields the following:

CTT is not sufficiently centered under port =
$0.003 \times 0.5 \times 0.8 = 0.002$

Operator Fails to Notice that the CTT Is Not Sufficiently Centered—The CTM operator centers the CTM grapple over the cask lid lift fixture using a two-step process. First, the CTM operator does a rough alignment using the bridge and trolley position indicators and sets the bell and shield skirt in place. Then the operator opens the cask port and performs a fine alignment using a camera alignment system. The operator is not looking for perfect alignment but would expect it to be close. At this point, the operator would have the opportunity to question the amount of distance needed to move the hoist to into position. Possible operator responses include: (1) the position is not off by much, (2) the initial placement of the bell is in question and it is repositioned (which may be easier to accomplish than to asking another crew member to move the CTT).

In this task, the CTM operator roughly centers the CTM over the cask port, lowers the shield, and opens the port and CTM gates. The operator needs to more accurately locate the grapple over the lid by moving the hoist within the bell. At this point, the operator has an opportunity to judge if the amount of movement required to align the grapple is too much for the lid to clear the edges of the port during the lift. In this case, it is not so much an observation failure (the operator can't help but observe the relative locations of the grapple and the lid) or a diagnosis failure (the operator knows the canister is not perfectly centered), but rather a decision error, where the operator decides that it doesn't matter that the cask is not centered ("it's close enough"). This can be represented by CREAM CFF I2, adjusted by the following CPCs with values not equal to 1.0.

- CFF I2: Decision error (either not making a decision or making a wrong or incomplete decision). The baseline HEP is 0.01.

- CPC "Available Time": With regard to the general level of time pressure for the task and the situation type, it would be easy to believe that there is adequate time since the consequences of taking more time are (from a safety perspective) insignificant. However, from a production perspective, this would be a significant setback since the CTM operator would have to get the CTT crew back to move the CTT, a time-consuming process. This time pressure could bias the operator towards a decision that "it's close enough." The CPC for an interpretation task with continuously inadequate available time is 5.0.

Applying these factors yields the following:

Operator fails to notice that CTT is not sufficiently centered = 0.01 × 5 = 0.05

Operator Fails to Notice Lid Tilt—The CTM operator is able to see the lid through the camera display. When the lid strikes the ceiling, it begins to tilt as the hoist continues to rise. The operator has the opportunity to notice the tilting lid before it potentially jams and has the opportunity to stop the lift. The prior unsafe action of failing to notice that the cask is too far off center could still lead the operator to be somewhat more careful and observant during the lift than if it had been closer to center (e.g., like the extra care a driver might show while pulling into a narrower than normal parking space).

If the operator is looking at the camera view during the lift, then the operator has the opportunity to observe the lid contacting the ceiling of the Cask Unloading Room and tilting into the port rather than rising straight through. The most likely failure is that the operator is not looking at the screen at the time that this occurs, which can be represented by CREAM CFF O3, adjusted by the following CPCs with values not equal to 1.0:

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

- CPC "Adequacy of Man–Machine Interface": There are two vulnerabilities in the man–machine interface for this observation. First, there is no alarm or indicator to alert the operator. Second, the camera view is not perfect. These are inherent to this type of operation but would make it more likely that the operator would not be looking at the screen at the time. Thus, the man–machine interface should be considered inappropriate with regard to success of this observation. The CPC for an observation task with inappropriate man–machine interface is 5.0.

Applying these factors yields the following:

Operator fails to notice lid tilt = 0.003 × 5 = 0.02

Operator "Locks" Lift Button into Position—Another way that the lift would go too long is if the operator were to use some inventive means to "lock" the button in place. The CTM lifts are a tedious task and require holding the button in place for long periods of time. There is no locking feature associated with the ASD that would keep the button in place; however, it is not inconceivable that, after many lifts have been done without an ASD failure, an operator would develop a creative technique to accomplish this. Since the operator develops trust in the ASD and the other system interlocks, the action would not be perceived as unsafe but rather as a clever way to free time to get ready for subsequent steps or perform other duties. Again, the operator might be less likely to do this if there are doubts about the positioning of the cask.

The quantification of this event is discussed in detail under Scenario 1(c). In this scenario, it is judged that there is no-bias dependency towards this failure that results from prior failures in the scenario. Therefore, the value used for the no-bias case is applied here:

Operator "locks" lift button into place = 0.05

Lid Catches and Jams in Port—Given the size of the lid in relation to the port, it is entirely possible that when it strikes the ceiling and tilts sideways, it still simply goes through the port at an angle without jamming.

The lid is smaller than the port, and a round object passing through a large round hole would generally be expected not to jam (unlike, for example, a square lid and a square hole where there are a number of orientations where jamming could occur). Nevertheless, for the purpose of this analysis, this is assessed as having "even odds" of jamming versus not jamming.

Lid catches and jams in port = 0.5

Load Cell Overload Interlock Fails—The load cell has an interlock that shuts off the hoist if it senses that the load exceeds the approved load for the hoist. The hoist straining to lift the lid jammed in the port would be one such condition. Since this would shut the hoist down prior to exceeding the ultimate capacity of the system, it would have to fail in order to cause a drop.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell interlock fails = 2.7E−5

Mechanical Failure of Hoist under Overload Causes Lid Drop—There are three potential failure modes that could cause the lid to detach from the hoist. The cable could fail, the grapple could break free from the lower block, or the lifting fixture could break free from the grapple or lid. However, just because the hoist keeps pulling does not mean that the lid falls (the hoist motor could overload and fail before the lid becomes detached from the hoist) or that the lid, once dropped, falls in an orientation that impacts the canister in the transportation cask (the orientation of the falling lid may cause it to only impact the transportation cask structure).

This event is quantified in Section E6.4.3.4.1.

Mechanical failure of hoist under overload causes lid drop = 0.1

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

Table E6.4-7. HEP Model for HFE Group #4 Scenario 1(d) for 200-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	CTT is not sufficiently centered under port	0.002
B	Operator fails to notice CTT not sufficiently centered	0.05
C	Operator fails to notice lid tilt and continues lift	0.02
D	Operator "locks" lift button into position	0.05
E	Lid catches and jams in port	0.5
F	Load cell overload interlock fails	2.7E−5
G	Mechanical failure of hoist under overload causes lid drop	0.1

NOTE: CTT = cask transfer trolley; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times (C + D) \times E \times F \times G =$$
$$0.002 \times 0.05 \times (0.02 + 0.05) \times 0.5 \times 2.7E{-5} \times 0.1 = (< 1E{-8}) \qquad \text{(Eq. E-13)}$$

E6.4.3.4.2.5 HFE Group #4 Scenario 1(e) for 200-OpCTMdrop001-HFI-COD

1. Operator activates grapple disengagement switch prematurely.
2. Load cell disengagement interlock fails.
3. Lid drops from grapple and strikes canister.

Operator Activates Grapple Disengagement Switch Prematurely—Once engaged with the lid, the grapple is supposed to remain engaged until the lid is placed in its staging area. The operator could prematurely activate grapple disengagement for one of two reasons: either the wrong control could be activated (e.g., when the operator is closing the port slide gate), or the operator could lose track of activity in the procedure, skip a number of steps, and prematurely actuate the control.

This is a straightforward case of taking an action out of sequence. This can be represented by CREAM CFF E4, adjusted by the following CPCs with values not equal to 1.0:

- CFF E4: Action performed out of sequence (e.g., repetitions, jumps, reversals). The baseline HEP is 0.003.

- CPC "Working Conditions": With regard to this potential unsafe action, the working conditions for the CTM operator are deemed to be advantageous. The CPC for an execution task with advantageous working conditions is 0.8.

- CPC "Adequacy of Training/Preparation": This routine action is well trained and performed often. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Operator activates grapple disengagement switch prematurely
$$= 0.003 \times 0.8 \times 0.8 = 0.002$$

Load Cell Disengagement Interlock Fails—One of the load cell interlocks is designed to disable the grapple disengagement circuit if a load is sensed. This interlock would have to fail in order for the operator's action to trigger the disengagement mechanism.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell disengagement interlock fails = 2.7E−5

Lid Drops from Grapple and Strikes Canister—In order for the lid to actually drop, the grapple disengagement mechanism would need to overcome the dead weight friction caused by the weight of the lid. In the case of the canister, this is clearly expected to be true, but the lid weighs much less than the canister; thus, the same expectation is not clear. However, there is still a chance that the grapple would not disengage or would not disengage while the lid is over the open cask port.

There are a number of factors that affect the likelihood of this event. First, in order to strike the canister the disengagement must occur over the canister, including that the slide gates are open. Second, the design of the grapple is such that it may not have the force to disengage when it is loaded (this is certainly true when lifting a canister, but perhaps less so when lifting a lid). Finally, the lid has to fall in an orientation such that it strikes the canister. Taking this all into consideration, the HRA team judges that it is justifiable to assign a 10 percent chance that this event would occur.

Lid drops from grapple and strikes canister = 0.1

HEP Calculation for Scenario 1(e)—The events in the HEP model for Scenario 1(e) are presented in Table E6.4-8.

Table E6.4-8. HEP Model for HFE Group #4 Scenario 1(e) for 200-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	Operator activates grapple disengagement switch prematurely	0.002
B	Load cell disengagement interlock fails	2.7E−5
C	Lid drops from grapple and strikes canister	0.1

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

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C = 0.002 \times 2.7E{-5} \times 0.1 = (< 1E{-8}) \quad \text{(Eq. E-14)}$$

E6.4.3.4.2.6 HEP for 200-OpCTMdrop001-HFI-COD

The Boolean expression for the overall HFE (all scenarios) for lifting a lid off a transportation cask follows:

200-OpCTMdrop001-HFI-COD (lid lift) =
HFE 1(a) + HFE 1(b) + HFE 1(c) + HFE 1(d) + HFE 1(e) = (<1E−8) +
1E−7 + (<1E−8) + (<1E−8) + (<1E−8) = 2E−7 (Eq. E-15)

The Boolean expression for the overall HFE (all scenarios) for placing a lid on an aging overpack follows:

200-OpCTMdrop001-HFI-COD (lid placement)
= HFE 1(a) + HFE 1(b) + HFE 1(e) = 2E−8 + 1E−7 + (<1E−8) = 2E−7 (Eq. E-16)

Except for DPCs, which only have a lid placement, all canisters have one lid lift and one lid placement as part of their processing. For simplicity, DPCs were conservatively modeled the same as other canisters, and the Boolean expression for the overall HFE for a lid lift and a lid placement follows:

200-OpCTMdrop001-HFI-COD (total) = 200-OpCTMdrop001-HFI-COD (lid lift)
+ 200-OpCTMdrop001-HFI-COD (lid placement) = 2E−7 + 2E−7 = 4E−7 (Eq. E-17)

E6.4.3.4.3 Quantification of HFE Scenarios for 200-OpCTMdrop002-HFI-COD: Operator Causes Drop of Canister during CTM Operations

E6.4.3.4.3.1 HFE Group #4 Scenario 2(a)

1. Crew member improperly installs grapple.
2. Primary grapple interlock gives false positive signal.
3. Operator fails to notice bad connection between hoist and grapple through camera.
4. Grapple/canister drops from hoist.

Crew Member Improperly Installs Grapple—Prior to a lift operation, a crew member prepares the CTM for the operation by installing the appropriate grapple for the type of canister to be processed. While it is possible that this operation does not need to be performed (it may be the same grapple as for the cask lid), it is uncertain how often this occurs, so this analysis considers that this action needs to be performed each time. The crew member can improperly secure the grapple to the hoist. This makes the grapple appear to be secured in place when it is not.

This is a straightforward matter of task execution. The task is simple and routine and can be represented by NARA GTT A5, adjusted by the following EPCs:

- GTT A5: Completely familiar, well-designed, highly practiced routine task performed to the 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.

- EPC 3: Time pressure. The full effect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOE anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The crew member probably feels a little more time pressure than that, so the APOE is set at 0.2.

- EPC 8: Poor environment. This EPC is applied not so much because the environment is poor, but rather that it is simply not optimal. The full effect EPC would be ×8, but this applies when working on the plant, with suit and breathing apparatus, possible access problems, and for more than 45 minutes so that fatigue sets in. The APOE anchor for 0.1 is for work in the plant with suit and breathing apparatus, but none of the other environmental stressors. In this task no breathing apparatus is required, but it is somewhat physically demanding. Given the tradeoffs, the APOE is set at 0.1.

- EPC 13: Operator underload/boredom. The full effect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOE anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOE is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Crew member improperly installs grapple} = 0.0001 \times [(11-1) \times 0.2 + 1] \times [(8-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.0006 \qquad \text{(Eq. E-18)}$$

Preoperational Check Fails to Note Improper Installation—There are two crew members responsible for preparing the CTM for each operation. The second crew member checks the first crew member's installation of the grapple, which provides an opportunity for the error to be detected. The second crew member also has activities to perform, and so checking the first crew member is a secondary function. In addition, the existence of the grapple/hoist interlock provides an expectation that any error will be detected.

For the action being analyzed, the second crew member has helped initially with the connection of the grapple to line it up but then moved on to other things. At best, the second crew member performs a cursory check at the end of the job. Since the crew member was involved in the early stages, there is a bias that the job was done correctly. It is concluded that the level of dependence is high. The baseline HEP for the checking, for checking routine tasks without a checklist, is best determined from THERP (Ref. E8.1.26, Table 20-22, item (2)), which is 0.2. The HEP adjusted for high dependence is from THERP (Ref. E8.1.26, Table 20-21, item (4)(e)), which is 0.6.

$$\text{Preoperational check fails to note improper installation} = 0.6$$

Grapple Interlock Gives False Positive Signal—Before beginning the lifting process, the operator should confirm engagement by checking the primary grapple engagement interlock. The indicator could give a false positive signal. This could result from a failure in the indicator itself or as the result of a partial engagement that generates a positive signal by triggering the sensor even though only partial engagement has occurred. Since the indicator system has not yet been designed and the specific detection approach has not been defined, this cannot be ruled out.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Grapple interlock gives false positive signal = 2.7E−5

Operator Fails to Notice Bad Connection between Hoist and Grapple through Camera—When the CTM operator is in the process of lifting the canister, the view through the camera shows the grapple and its connection to the hoist. The operator is not focused on that connection; rather, the operator's focus is on lining up the grapple with the lifting device. However, as the lift begins, the operator is supposed to watch through the cameras. This gives the operator the opportunity to note that the grapple is not properly connected (e.g., unexpected canister movement to one side or tilting of the grapple). This is an opportunity for the operator to question the stability of the connection and to lower the canister back down to recheck the connection. However, the operator does not expect any problems in this simple operation and tends to believe that any perceived problems are illusions caused by the distortions of viewing through a camera.

This action is best represented by the CREAM 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 "Adequacy of Man–Machine Interface": For this particular observation, the use of a camera view (while the only practical means) is somewhere between tolerable and inappropriate. The CPC for an observation task with tolerable man–machine interface is 1.0, and for inappropriate is 5.0. With regard to being able to actually observe the condition of the grapple lock pin, the CPC is set as 4.0.
- CPC "Number of Simultaneous Goals": The operator is primarily focusing on properly aligning the bell and hoist, opening the ports, and grappling the lid. While it could be argued that this is not "more than capacity," it certainly relegates looking at the grapple/hoist connection to a secondary action. It is therefore deemed appropriate to apply the more than capacity CPC, which is 2.0.
- 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.

Operator fails to notice bad connection between hoist and grapple through camera = $0.003 \times 4 \times 2 \times 0.8 = 0.02$

Grapple/Canister Drops from Hoist—Just because the lift is occurring with an improper grapple installation does not mean that the lid and grapple fall. The safety margin built into these systems means that it is possible that the lift and placement can be completed successfully even with improper installation.

This event is quantified in Section E6.4.3.4.1.

Grapple/canister drops from hoist = 0.25

HEP Calculation for Scenario 2(a)—The events in the HEP model for Scenario 2(a) are presented in Table E6.4-9.

Table E6.4-9. HEP Model for HFE Group #4 Scenario 2(a) for 200-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	Crew member improperly installs grapple	0.0006
B	Preoperational check fails to note improper installation	0.6
C	Grapple interlock gives false positive signal	2.7E−5
D	Operator fails to notice bad connection between hoist and grapple through camera	0.02
E	Grapple/canister drops from hoist	0.25

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

Source: Original

The Boolean expression for this scenario for a DPC/transportation cask lift follows:

$$A \times B \times C \times D \times E = 0.0006 \times 0.6 \times 2.7E{-5} \times 0.02 \times 0.25 = (< 1E{-8}) \quad \text{(Eq. E-19)}$$

E6.4.3.4.3.2 HFE Group #4 Scenario 2(b) for 200-OpCTMdrop002-HFI-COD

1. Operator fails to fully engage grapple.
2. Grapple engagement interlock gives false positive signal.
3. Operator fails to notice grapple not fully engaged through camera.
4. Canister drops from grapple.

CTM Operator Fails to Fully Engage Grapple—The operator engages the grapple from the control panel. The grapple can be roughly positioned using the alignment guides for the CTM and the hoist height indicator on the control panel, but final alignment must be done visually using the view from the cameras provided on the grapple. Once the operator believes the grapple is aligned, the operator engages the grapple with the lift fixture and confirms through the camera that the grapple is engaged. If the operator sees that the grapple has not properly engaged, then the operator disengages and repositions the grapple and then tries again to engage the grapple.

In this task, the operator aligns the grapple visually using the camera view and then engages the grapple. If it is not aligned properly, it does not fully engage. This unsafe action can be best represented by the task execution error NARA GTT A1, adjusted by the following CPCs:

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

- EPC 3: Time pressure. The full effect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOE anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The crew member probably feels a little more time pressure than that, so the APOE is set at 0.2.

- EPC 11: Poor, ambiguous, or ill-matched system feedback. This EPC is applied to account for the need to observe the operation through cameras. The full effect EPC would be ×4. The full effect is applicable when legibility is poor or label is obscured or where the layout of controls makes visual access and physical access difficult. The use of camera view is deemed to represent full effect. The APOE is set at 1.0.

- EPC 13: Operator underload/boredom. The full effect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOE anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOE is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Operator fails to fully engage grapple} = 0.005 \times [(11-1) \times 0.2 + 1] \times [(4-1) \times 1.0 + 1] \times [(3-1) \times 0.1 + 1] = 0.07 \quad \text{(Eq. E-20)}$$

Grapple Engagement Interlock Gives False Positive Signal—Before beginning the lifting process, the operator should confirm engagement by checking the grapple engagement interlock. The indicator could give a false positive signal. This could result from a failure in the indicator itself or as the result of a partial engagement that generates a positive signal by triggering the sensor even though only partial engagement has occurred. Since the indicator system has not yet been designed and the specific detection approach has not been defined, this cannot be ruled out.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

$$\text{Grapple engagement interlock gives false positive signal} = 2.7\text{E}-5$$

CTM Operator Fails to Notice Grapple Not Fully Engaged through Camera—As the lift begins, the operator is supposed to watch through the cameras. This gives the operator the opportunity to note that the grapple is not properly engaged (e.g., unexpected canister movement to one side or tilting of the grapple), which provides the operator the opportunity to question the stability of the connection and to lower the canister back down to recheck the connection. However, the operator does not expect any problems in this simple operation and tends to believe that any perceived problems are illusions caused by the distortions of viewing through a camera.

In this case, the operator's check is a self-check, again through the camera. The CTM operator believes that the correct action was performed initially, and this was confirmed by the false positive from the interlock, so this observation is deemed completely dependent on the prior actions. Using THERP (Ref. E8.1.26, Table 20-21) to assess dependency, item (5) for complete dependency:

Operator fails to notice grapple not fully engaged through camera = 1.0

Canister Drops from Grapple—Just because the lift is occurring with an improper grapple engagement does not mean that the canister falls. The safety margin built into these systems means that it is possible that the lift and placement can be completed successfully even with improper installation.

This event is quantified in Section E6.4.3.4.1.

Canister drops from grapple = 0.25

HEP Calculation for Scenario 2(b)—The events in the HEP model for Scenario 2(b) are presented in Table E6.4-10.

Table E6.4-10. HEP Model for HFE Group #4 Scenario 2(b) for 200-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	Operator fails to fully engage grapple	0.07
B	Grapple engagement interlock gives false positive signal	2.7E−5
C	Operator fails to notice grapple not fully engaged through camera	1.0
D	Canister drops from grapple	0.25

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

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C \times D = 0.07 \times 2.7E{-5} \times 1.0 \times 0.25 = 5E{-7} \qquad \text{(Eq. E-21)}$$

E6.4.3.4.3.3 HFE Group #4 Scenario 2(c) for 200-OpCTMdrop002-HFI-COD (Applies to DPCs only)

1. CTT is not sufficiently centered under port.

2. Operator fails to notice CTT not sufficiently centered.

3. Operator fails to notice DPC contacting ceiling and continues lift OR operator "locks" lift button into position.

4. Load cell overload interlock fails.

5. Mechanical failure of hoist under overload causes DPC drop (NOTE: This scenario only applies to DPCs because the transportation cask lid was removed in the prep area).

CTT Is Not Sufficiently Centered under Port—This unsafe action actually occurs prior to this operation, during movement of the CTT into the Cask Unloading Room. The CTT operator brings the unit into the Cask Unloading Room and locates it centered directly under the cask port by aligning it against end stops that properly locate it and by using markings on the floor. If the cask is not properly centered, it is possible that the DPC could strike the ceiling around the cask port rather than rising smoothly through the cask port. This only applies to DPCs because their transportation cask lids are removed in the preparation area. For all other waste forms, any misalignment would be discovered during the lid lift by the CTM. In order for the DPC to hit the Cask Unloading Room ceiling during lift, the cask would have to be off-center by at least a few feet.

The unsafe action results from stopping the CTT prematurely and leaving it at least a number of feet short of the proper location. This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

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

- CPC "Available Time": There is adequate time to perform this task. The only time pressure is the desire to keep the process moving, but the consequences are insignificant. The CPC for an execution task with adequate time is 0.5.

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

The above parameters were the same as those applied to failure to properly center the CTT for a lid, where only being about a foot or two out of position could cause a problem. For the case of a canister, the miss must be by at least a few feet in order for the canister to strike the ceiling on the way up. The HRA team believes it is inappropriate to apply the same number to both unsafe actions and deems it reasonable to further reduce the HEP for the unsafe action by a factor of two to account for this (a multiplier of 0.5).

Applying these factors yields the following:

CTT is not sufficiently centered under port (DPC/transportation cask)
$$= 0.003 \times 0.5 \times 0.8 \times 0.5 = 0.001$$

Operator Fails to Notice that the CTT Is Not Sufficiently Centered—The CTM operator centers the CTM grapple over the cask lid lift fixture using a two-step process. First the CTM operator does a rough alignment using the bridge and trolley position indicators and sets the bell and shield skirt in place. Then the operator opens the cask port and performs a fine alignment using a camera alignment system. The operator is not looking for perfect alignment, but would expect it to be close. At this point, the operator has an opportunity to judge if the amount of movement required to align the grapple is too much for the canister to clear the edges of the port during the lift. In this case, it is not so much an observation failure (the operator can't help but observe the relative locations of the grapple and the canister) or a diagnosis failure (the operator knows the cask is not perfectly centered), but rather a decision error, where the operator decides that it doesn't matter that the cask is not centered ("it's close enough"). This can be represented by CREAM CFF I2, adjusted by the following CPCs with values not equal to 1.0.

- CFF I2: Decision error (either not making a decision or making a wrong or incomplete decision). The baseline HEP is 0.01.
- CPC "Available Time": With regard to the general level of time pressure for the task and the situation type, it would be easy to believe that there is adequate time since the consequences of taking more time are (from a safety perspective) insignificant. However, from a production perspective, this would be a significant setback since the CTM operator would have to get the CTT crew back to move the CTT, a time-consuming process. This time pressure could bias the operator towards a decision that "it's close enough." The CPC for an interpretation task with continuously inadequate available time is 5.0.

Applying these factors yields the following:

Operator fails to notice that CTT not sufficiently centered = 0.01 × 5 = 0.05

Operator Fails to Notice DPC Contacting Ceiling and Continues Lift—The CTM operator is able to see the DPC through the camera display. When the DPC strikes the ceiling it stops as the hoist continues to try to rise. The operator then has an opportunity to notice the stopped CTM before it stops the lift. The prior unsafe action of failing to notice that the cask is too far off center could lead the operator to be somewhat more careful and observant during the lift than if it had been closer to center (e.g., like the extra care a driver might show while pulling into a narrower than normal parking space).

If the operator is looking at the camera view during the lift, there is an opportunity to observe the DPC contacting the ceiling of the Cask Unloading Room and stopping rather than rising straight through. The most likely failure is not looking at the screen at the time this occurs, which can be represented by CREAM CFF O3, adjusted by the following CPCs with values not equal to 1.0:

- CFF O3: Observation not made (omission). The baseline HEP is 0.003.
- CPC "Adequacy of Man–Machine Interface": There are two vulnerabilities in the man-machine interface for this observation. First, there is no alarm or indicator to alert the operator. Second, the camera view is not perfect. These are inherent to this type of

operation but would make it more likely that the operator would not be looking at the screen at the time. Thus, the man–machine interface could be considered inappropriate with regard to success of this observation (as it was for scenario 1(e)). However, the fact that the magnitude of the CTT offset required to cause a problem is so much greater in this case argues for a somewhat lesser adjustment. That is, the man–machine interface is somewhat better with regard to this failure, and it is more likely that the operator is looking and sees the contact. The CPC for an observation task with inappropriate man–machine interface is 5.0. The HRA team has determined that a CPC of 3.0 is more appropriate in this case.

Applying these factors yields the following:

Operator fails to notice DPC contacting ceiling and continues lift
$= 0.003 \times 3 = 0.01$

Operator "Locks" Lift Button into Position—Another way that the lift would go too long is if the operator were to use some inventive means to "lock" the button in place. The CTM lifts are a tedious task and require holding the button in place for long periods of time. There is no locking feature associated with the ASD that would keep the button in place; however, it is not inconceivable that, after many lifts have been done without ASD failure, an operator would develop a creative technique to accomplish this. Since the operator develops trust in the ASD and the other system interlocks, the action would not be perceived as unsafe but rather as a clever way to free time to get ready for subsequent steps or perform other duties. Again, the operator might be less likely to do this if there are doubts about the positioning of the cask.

The quantification of this event is discussed in detail under Scenario 1(c). In this scenario, it is judged that there is no-bias dependency towards this failure that results from prior failures in the scenario. Therefore, the value used for the no-bias case (0.05) could be applied here. However, similar to the previous discussion, the HRA team believes that the magnitude of the CTT offset required to cause a problem actually creates a bias in the operator against taking any shortcuts (as opposed to no bias), so that a further reduction of 0.5 should be applied.

Operator "locks" lift button into place $= 0.05 \times 0.5 = 0.03$

Load Cell Overload Interlock Fails—The load cell has an interlock that shuts off the hoist if it senses that the load exceeds the approved load for the hoist. The hoist straining to lift the DPC in contact with the ceiling would be one such condition. Since this would shut the hoist down prior to exceeding the ultimate capacity of the system, it would have to fail in order to cause a drop.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell interlock fails = 2.7E−5

Mechanical Failure of Hoist under Overload Causes DPC Drop—There are three potential failure modes that could cause the canister to detach from the hoist. The cable could fail, the grapple could break free from the lower block, or the lifting fixture could break free from the grapple or DPC. However, just because the hoist keeps pulling does not mean that the DPC falls (the hoist motor could overload and fail before the DPC becomes detached from the hoist).

This event is quantified in Section E6.4.3.4.1.

Mechanical failure of hoist under overload causes DPC drop = 0.25

HEP Calculation for Scenario 2(c)—The events in the HEP model for Scenario 2(c) are presented in Table E6.4-11.

Table E6.4-11. HEP Model for HFE Group #4 Scenario 2(c) for 200-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	CTT is not sufficiently centered under port	0.001
B	Operator fails to notice CTT not sufficiently centered	0.05
C	Operator fails to notice DPC contacting ceiling and continues lift	0.01
D	Operator “locks” lift button into position	0.03
E	Load cell overload interlock fails	2.7E−5
F	Mechanical failure of hoist under overload causes DPC drop	0.25

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

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times (C + D) \times E \times F = 0.001 \times 0.05 \times (0.01 + 0.03) \times 2.7\text{E}{-5} \times 0.25 = (< 1\text{E}{-8}) \qquad \text{(Eq. E-22)}$$

E6.4.3.4.3.4 HEP for HFE 200-OpCTMdrop002-HFI-COD

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

$$\text{200-OpCTMdrop002-HFI-COD (DPC)} = \text{HFE 2(a)} + \text{HFE 2(b)} + \text{HFE 2(c)} = (<1\text{E}{-8}) + 5\text{E}{-7} + (<1\text{E}{-8}) = 5\text{E}{-7} \qquad \text{(Eq. E-23)}$$

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

$$\text{200-OpCTMdrop002-HFI-COD (TAD)} = \text{HFE 2(a)} + \text{HFE 2(b)} = (<1\text{E}{-8}) + 5\text{E}{-7} = 5\text{E}{-7} \qquad \text{(Eq. E-24)}$$

E6.4.3.4.4 Quantification of HFE Scenarios for 200-OpCTMImpact1-HFI-COD: Operator Moves the CTM while Canister or Object Is below or between Levels

E6.4.3.4.4.1 HFE Group #4 Scenario 3(a) for 200-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in lid lift mode (TAD canisters).
2. Operator fails to notice that lift stops too soon.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Leaves CTM in Lid Lift Mode (TAD canisters)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. It should be in lid lift mode because the lid was lifted right before the canister. Failing to reset for a canister lift would result in the canister stopping part way through the port.

Setting the CTM system to the appropriate lift mode prior to performing a lift is fundamental to the operation, not simply a step in a procedure that can be missed. The initial action to set the mode is quite simple, so the only realistic way that the operator can leave the ASD in lid lift mode is to completely fail to take any actions to set the CTM system for a lift. This failure can be represented by NARA GTT B3, adjusted by the following EPCs:

- GTT B3: Set system status as part of routine operations using strict administratively controlled procedures. The baseline HEP is 0.0007.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The baseline HEP is used without adjustment.

Operator leaves CTM in lid lift mode = 0.0007

Operator Fails to Notice that Lift Stops too Soon—Lifting the canister takes on the order of ten minutes, whereas lifting the lid takes only on the order of three minutes. Since the operator has to hold the lift button in or the lift stops, there is an opportunity to notice that the hoist has stopped sooner than expected. On the control panel the operator would have the camera view and also the hoist position indication, either of which can confirm that the canister has not been fully lifted. Failure to do so would result in continuing the operations with the canister between floors.

The operator is supposed to hold the lift button until the lift automatically stops. The operator has performed this operation many times in the past and has an instinctive feel for how long the lift takes. A canister lift should take around three times as long as a lid lift. If the operator feels it has not taken long enough, the camera and the indicators on the control panel can provide confirmation that the lift was prematurely terminated. Failing to recognize the short lift (and thus an implied failure to question the result of the action) could be an observation error (CREAM CFF O2, wrong identification made, or O3, observation not made). But the more conservative and more applicable approach is represented by the interpretation error CREAM CFF I1, adjusted by the following CPCs with values not equal to 1.0:

- CFF I1: Faulty diagnosis (either a wrong diagnosis or an incomplete diagnosis). The baseline HEP is 0.2.

- CPC "Working Conditions": The operator has optimal working conditions in the control room. The CPC for an interpretation task with advantageous working conditions is 0.8.

- CPC "Available Time": The operator clearly has adequate time before beginning the next steps in the process to realize that the amount of time spent in the lift is not reasonable for a canister lift. The CPC for an interpretation task with adequate available time is 0.5.

- 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:

$$\text{Operator fails to notice lift is taking too long} = 0.2 \times 0.8 \times 0.5 \times 0.8 = 0.07$$

Operator Fails to Close Port Slide Gate—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights are in an incorrect state (either both on or both off, depending on design).

The operator is supposed to close the port slide gate prior as a part of the lift and transfer process. This is an EOO that can most closely be represented by CREAM CFF E5, adjusted by the following CPCs with values not equal to 1.0:

- CFF E5: Action missed, not performed (omission), including the omission of the last actions in a series. The baseline HEP is 0.03.

- CPC "Available Time": There is adequate time available. The CPC for an execution task with adequate time is 0.5.

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

Applying these factors yields the following:

$$\text{Operator fails to close port slide gate} = 0.03 \times 0.5 \times 0.8 = 0.01$$

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—In this case, the operator has slide gate open/close indicator lights that are in an incorrect state (either both on or both off, depending on design).

The action of closing the port slide gate is simple. In this scenario, the gate does not close all the way because the canister is in the way. The operator has visible feedback on the failure of the gate to close because the "open" (or "green") light on the control panel stays on and the "closed" (or "red") light also comes on and stays on. Both lights on at the same time signify that the port is neither fully open nor fully closed. The problem can be easily confirmed by looking at the camera or checking the status of the light curtain at the bottom of the bell. This unsafe action can be represented by NARA GTT C1, adjusted by the following EPCs:

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

- EPC 3: Time pressure. The full effect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOE anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOE is set at 0.1.

- EPC 13: Operator underload/boredom. The full effect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOE anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOE is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Operator fails to notice that port slide gate does not fully close} \\ = 0.0004 \times [(11-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.001 \qquad \text{(Eq. E-25)}$$

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

The baseline HEP for failure to close this gate would be the same as for the similar unsafe action for the port slide gate.

Operator fails to close CTM slide gate (independent) = 0.01

However, this would only apply in the case where the earlier unsafe action was failure to notice that the port slide gate had failed to close. In the case where the earlier unsafe action was failure to close the port slide gate, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26, Table 20-21), the HEP follows:

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—The baseline HEP for failure to notice that this gate did not fully close would be the same as for the similar unsafe action for the port slide gate.

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

However, this would only apply in the case where the earlier unsafe action was failure to close the port slide gate. In the case where the earlier unsafe action was failure to notice that the port slide gate did not fully close, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26, Table 20-21), the HEP follows:

Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(a)—The events in the HEP model for Scenario 3(a) are presented in Table E6.4-12.

Table E6.4-12. HEP Model for HFE Group #4 Scenario 3(a) for 200-OpCTMImpact1-HFI-NOD

Designator	Description	Probability
A	Operator leaves CTM in lid lift mode	0.0007
B	Operator fails to notice that lift stops too soon	0.07
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G =$$
$$0.0007 \times 0.07 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 =$$
$$0.0007 \times 0.07 \times 0.006 \times -2.7E{-}05 = 1E{-}09 \times -2.7E{-}05$$

Truncating the human component to 1E−05, this scenario simplifies to:

$$1E{-}05 \times -2.7E{-}05 = 3E{-}10 = (<1E{-}8) \qquad \text{(Eq. E-26)}$$

E6.4.3.4.4.2 HFE Group #4 Scenario 3(b) for 200-OpCTMImpact1-HFI-COD

1. Operator places CTM in lid lift mode (DPCs).
2. Operator fails to notice that lift stops too soon.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Inadvertently Places CTM in Lid Lift Mode (DPCs)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. For DPC operations, the ASD is in maintenance (or manual) lift mode because this is the default positioning. Failing to reset for canister lift would result in the canister stopping part way through the port.

The CTM operator is supposed to set the CTM system to the appropriate lift mode prior to performing a lift. This is fundamental to the operation, not simply a step in a procedure that can be missed. For the situation involving DPCs, the ASD has been in maintenance mode as a default condition; therefore, the operator must inadvertently set the ASD to lid lift mode rather than canister lift mode. There are only two modes to choose from: lid lift and canister lift. The ASD control is a screen where the operator can scroll between the choices to pick the appropriate lift mode. The act of selecting the wrong mode from these two can be best represented by the task execution error NARA GTT A1, adjusted by the following CPCs:

- NARA 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.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The ASD control system requests confirmation from the operator (e.g., "You have selected canister lift. Confirm Y/N"). The baseline HEP is used without adjustment.

Operator inadvertently places CTM in lid lift mode (DPCs) = 0.005

Operator Fails to Notice that Lift Stops too Soon—Lifting the canister takes on the order of ten minutes, whereas lifting the lid takes only on the order of three minutes. Since the operator has to hold the lift button in or the lift stops, the operator has an opportunity to notice that the hoist has stopped sooner than expected. In front on the control panel there is a camera view and also the hoist position indication, either of which can confirm the suspicion that the canister has not been fully lifted. Failure to do so would result in a continuation of the operations with the canister between floors.

The operator is supposed to hold the lift button until the lift automatically stops. The operator has performed this operation many times in the past, and has an instinctive feel for how long the lift takes. A canister lift should take around three times as long as a lid lift. If the operator feels it has not taken long enough, the operator need only look at the camera and the indicators on the control panel. Failing to recognize the short lift (and thus an implied failure to question the result of the action) can be represented by CREAM CFF I1, adjusted by the following CPCs with values not equal to 1.0:

- CFF I3: Faulty diagnosis (either a wrong diagnosis or an incomplete diagnosis). The baseline HEP is 0.2.

- CPC "Working Conditions": The operator has optimal working conditions in the control room. The CPC for an interpretation task with advantageous working conditions is 0.8.

- CPC "Available Time": The operator clearly has adequate time before beginning the next steps in the process to realize that the amount of time spent in the lift is not reasonable for a canister lift. The CPC for an interpretation task with adequate available time is 0.5.

- 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:

$$\text{Operator fails to notice lift is taking too long} = 0.2 \times 0.8 \times 0.5 \times 0.8 = 0.07$$

Operator Fails to Close Port Slide—The operator is supposed to close the port slide gate as soon as the lift is completed as a part of the lift and transfer process. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights would be in an incorrect state (either both on or both off, depending on design).

This is an EOO that can most closely be represented by CREAM CFF E5, adjusted by the following CPCs with values not equal to 1.0:

- CFF E5: Action missed, not performed (omission), including the omission of the last actions in a series. The baseline HEP is 0.03.

- CPC "Available Time": There is adequate time available. The CPC for an execution task with adequate time is 0.5.

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

Applying these factors yields the following:

$$\text{Operator fails to close port slide gate} = 0.03 \times 0.5 \times 0.8 = 0.01$$

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—The action of closing the port slide gate is simple. In this scenario, the gate does not close all the way because the canister is in the way. The operator has visible feedback on the failure of the gate to close because the "open" (or "green") light on the control panel stays on and the "closed" (or "red") light also comes on and stays on. Both lights on at the same sign signify that the port is neither fully open nor fully closed. The problem can be easily confirmed by looking at the camera or checking the status of the light curtain at the bottom of the bell. This unsafe action can be represented by NARA GTT C1, adjusted for the following EPCs:

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

- EPC 3: Time pressure. The full effect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOE anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOE is set at 0.1.

- EPC 13: Operator underload/boredom. The full effect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOE anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOE is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Operator fails to notice that port slide gate does not fully close} = 0.0004 \times [(11-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.001 \qquad \text{(Eq. E-27)}$$

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. This failure would go unnoticed if the operator either skipped this step or performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

Operator fails to close CTM slide gate (independent) = 0.01

However, this would only apply in the case where the earlier unsafe action was failure to notice that the port slide gate had failed to close. In the case where the earlier unsafe action was failure to close the port slide gate, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26, Table 20-21), the HEP follows:

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—The baseline HEP for failure to notice this gate did not fully close would be the same as for the similar unsafe action for the port slide gate.

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

However, this would only apply in the case where the earlier unsafe action was failure to close the port slide gate. In the case where the earlier unsafe action was failure to notice that the port slide gate did not fully close, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26, Table 20-21), the HEP follows:

Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (i.e., the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(b)—The events in the HEP model for Scenario 3(b) are presented in Table E6.4-13.

Table E6.4-13. HEP Model for HFE Group #4 Scenario 3(b) for 200-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator inadvertently places CTM in lid lift mode	0.005
B	Operator fails to notice that lift stops too soon	0.07
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.005 \times 0.07 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 0.005 \times 0.07 \times 0.006 \times 2.7E{-}05 = 2E{-}06 \times 2.7E{-}05$$

Truncating the human component to 1E−05, this scenario simplifies to the following:

$$1E{-}05 \times 2.7E{-}05 = 3E{-}10 = (<1E{-}8) \quad \text{(Eq. E-28)}$$

E6.4.3.4.4.3 HFE Group #4 Scenario 3(c) for 200-OpCTMImpact1-HFI-COD

1. Operator puts CTM in maintenance mode (TAD canisters)
2. Operator terminates lift prior to automatic stop
3. Operator fails to close port slide gate OR fails to notice that it does not fully close
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Puts CTM in Maintenance Mode (TAD canisters)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. It should be in lid lift mode because the lid was lifted right before the canister. Placing it in the maintenance mode instead of the canister lift mode removes the ASD height control set point and also defeats the CTM slide gate interlock (since maintenance mode would allow CTM movement with the slide gate open). In order to place it into maintenance mode, the operator is required to enter a password.

In this case, the operator commits the unsafe action of placing the CTM in maintenance mode. This is not easy to do; if the operator inadvertently selects this mode, the operator is asked to confirm the selection and is also required to enter a password, which is not required for the selection of canister mode. This can be represented by NARA GTT A5, adjusted for the following EPCs:

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

- EPC 6: A means of suppressing or overriding information or features that are too easily accessible. In this case, while a warning is given and a password is required, the operator can still override the feature and enter manual mode. The full effect is ×9. The APOE anchor for 0.5 is for something overridden on a regular basis. The APOE anchor for 0.1 is for something overridden once in a while. Other considerations for a reduction from full effect are a good interface design and good safety culture. Since maintenance mode is required on a regular basis, but there are other mitigating factors, it appears reasonable for this task that the APOE be set at 0.3.

Using the NARA HEP equation yields the following:

$$\text{Operator puts CTM in maintenance mode} = 0.0001 \times [(9-1) \times 0.3 + 1] = 0.0004 \qquad \text{(Eq. E-29)}$$

Operator Terminates Lift Prior to Automatic Stop—The operator is supposed to hold the lift button until the lift automatically stops. This happens even in the maintenance mode since the interlocks that prevent two-blocking are still active, and the CTM transfer sequence can still be completed successfully. However, if the operator terminates the lift prematurely, the canister could still be between floors.

The unsafe action results from stopping the hoist prematurely and leaving the canister below or between the floors (i.e., a number of feet short of the proper location). This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

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

There are no CPCs that are deemed to have values not equal to 1.0 for this action.

Applying these factors yields the following:

Operator terminates lift prior to automatic stop = 0.003

Operator Fails to Close Port Slide Gate—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister).

This value is the same as for Scenario 3(a):

Operator fails to close port slide gate = 0.01

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice that port slide gate does not fully close = 0.001

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design)

This value is the same as for Scenario 3(a):

Operator fails to close CTM slide gate (independent) = 0.01

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels. NOTE: The maintenance mode does not bypass the shield skirt/slide gate interlock; this interlock cannot be bypassed.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(c)—The events in the HEP model for Scenario 3(c) are presented in Table E6.4-14.

Table E6.4-14. HEP Model for HFE Group #4 Scenario 3(c) for 200-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator puts CTM in maintenance mode	0.0004
B	Operator terminates lift prior to automatic stop	0.003
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.0004 \times 0.003$$
$$\times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 6E{-}09 \times 2.7E{-}5$$

Truncating the human failure component, the HEP for this scenario becomes:

$$1E{-}5 \times 2.7E{-}5 = (<1E{-}08) \quad \text{(Eq. E-30)}$$

E6.4.3.4.4.4 HFE Group #4 Scenario 3(d) for 200-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in maintenance mode (DPCs).
2. Operator terminates lift prior to automatic stop.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Leaves CTM in Maintenance Mode (DPCs)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. For DPC operations, the ASD is in maintenance (or manual) lift mode because this is the default positioning. Leaving it in the maintenance mode instead of the canister lift mode removes the ASD height control set point and also defeats the CTM slide gate interlock (since maintenance mode allows CTM movement with the slide gate open).

In this case, this leaves the ASD in maintenance mode, which is the default position for DPC operations. The initial action to set the mode is quite simple, so the only realistic way that the operator can leave the ASD in maintenance mode is to completely fail to take any actions to set the CTM system for a lift. This failure can be represented by NARA GTT B3, and adjusted by the following EPCs:

- GTT B3: Set system status as part of routine operations using strict administratively controlled procedures. The baseline HEP is 0.0007.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The baseline HEP is used without adjustment.

Operator leaves CTM in maintenance mode = 0.0007

Operator Terminates Lift Prior to Automatic Stop—The operator is supposed to hold the lift button in until the lift automatically stops. This happens even in the maintenance mode since the interlocks that prevent two-blocking are still active, and the CTM transfer sequence can still be completed successfully. However, if the operator terminates the lift prematurely, the canister could still be between floors. The unsafe action results from stopping the hoist prematurely and leaving the canister below or between the floors (i.e., a number of feet short of the proper location). This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

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

- There are no CPCs that are deemed to have values not equal to 1.0 for this action.

Applying these factors yields the following:

Operator terminates lift prior to automatic stop = 0.003

Operator Fails to Close Port Slide Gate—This value is the same as for Scenario 3(a).

Operator fails to close port slide gate = 0.01

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a).

Operator fails to notice that port slide gate does not fully close = 0.001

Operator Fails to Close CTM Slide Gate—This value is the same as for Scenario 3(a).

Operator fails to close CTM slide gate (independent) = 0.01

Operator fails to close CTM slide gate (given failure to close port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a).

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

Operator fails to notice CTM slide gate does not fully close
(given failure to notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels. NOTE: The maintenance mode does not bypass the shield skirt/slide gate interlock; this interlock cannot be bypassed.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(d)—The events in the HEP model for Scenario 3(d) are presented in Table E6.4-15.

Table E6.4-15. HEP Model for HFE Group #4 Scenario 3(d) for 200-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator leaves CTM in maintenance mode	0.0007
B	Operator terminates lift prior to automatic stop	0.003
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability; HFE = human failure event.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.0007 \times 0.003 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 0.0004 \times 0.003 \times 0.005 \times 2.7E{-}05 = 6E{-}09 \times 2.7E{-}5$$

Truncating the human failure component, the HEP for this scenario becomes:

$$1E{-}5 \times 2.7E{-}5 = (<1E{-}08) \quad \text{(Eq. E-31)}$$

E6.4.3.4.4.5 HEP for HFE 200-OpCTMImpact1-HFI-COD

To be conservative, all failure modes for this HFE are considered to be applicable to both TAD canister and DPC lifts; therefore, the Boolean expression for the overall HFE (all scenarios) follows:

$$\text{200-OpCTMImpact1-HFI-COD} = \text{HFE 3(a)} + \text{HFE 3(b)} + \text{HFE 3(c)} + \text{HFE 3(d)} = (<1E{-}8) + (<1E{-}8) + (<1E{-}8) + (<1E{-}08) = 4E{-}8 \quad \text{(Eq. E-32)}$$

NOTE: For lifting objects (transportation cask or aging overpack lids), the only failure mode that is applicable is 3(d); therefore, 4E−8 conservatively models movement with the lid below the floor.

E6.4.3.4.5 Quantification of HFE Scenarios for 200-OPCTMDirExp1-HFI-NOD: Operator Causes Direct Exposure during CTM Activities (Second Floor)

E6.4.3.4.5.1 HFE Group #4 Scenario 4(a) for 200-OpCTMDirExp1-HFI-NOD

1. Worker violates administrative control by entering the Canister Transfer Room during canister transfer.

2. Operator fails to close port gate before raising shield skirt.

Worker Violates Administrative Control by Entering the Canister Transfer Room during Canister Transfer—If a worker enters the Canister Transfer Room during canister transfer operations, there is a potential for direct exposure. There are several administrative controls restricting personnel from entering the Canister Transfer Room during canister transfer. These controls include the following:

- Personnel are only allowed in the Canister Transfer Room during prescheduled times.

- All personnel must check in with the control room (where the CTM is controlled) before entering the Canister Transfer Room.

If these controls are violated and a person enters the Canister Transfer Room when transfer operations are occurring, that person increases the potential to be exposed.

Any worker who wishes to enter the Canister Transfer Room needs to get permission to do so from a supervisor. If a worker violates this requirement, there is nothing that stops the worker from entering the room. However, this administrative control is fundamental to the operation of the facility and applies to entry to all important (i.e., radiation-controlled) areas of the facility. This is best represented by NARA GTT A5, adjusted by the following EPCs:

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

- EPC 7: No obvious means of reversing an unintended action. The GTT HEP is based on there being time to correct potential errors. This does not exist for this task. The maximum effect of the EPC is 9, which applies when there is no means of recovering from an unintended action once executed. Given that the error is not correctable, the APOE is set at 1.0.

This assessment does not give credit for the worker believing that there is a need to enter the Canister Transfer Room in the first place.

Applying the NARA HEP equation yields the following:

$$\text{Worker violates administrative control by entering the Canister Transfer Room during canister transfer} = 0.0001 \times [(9-1) \times 1.0 + 1] = 0.0009 \qquad \text{(Eq. E-33)}$$

Operator Fails to Close Port Gate before Lifting Shield Skirt—Just entering the Canister Transfer Room during canister transfer cannot result in an exposure since the entire operation is shielded. Therefore, to result in an exposure, the shielding must be compromised. After the canister is placed in a receptacle (e.g., waste package, aging overpack, staging rack), the CTM operator is supposed to close the port gate and then raise the shield skirt and move the CTM. If the operator fails to close the port gate before the shield skirt is raised and before the CTM is moved, then the crew members on the floor of the Canister Transfer Room would get a direct exposure. This is a skill-based action that is performed as part of every CTM movement over a port gate. This action is completely independent of the worker entering the room.

This is a task execution error with no feedback and its consequences are immediate (i.e., no potential for recovery). This most closely corresponds to the task execution error CREAM CFF E5, adjusted for the following CPCs with values not equal to 1.0.

- CFF E5: Missed action. The baseline HEP is 0.03.
- CPC "Working Conditions": The working conditions for the operator are in a control room with a favorable environment. The CPC for advantageous working conditions for an execution task is 0.8.
- CPC "Availability of Procedures": With regard to the notification step, the procedures and checklist clearly list that this task needs to be performed. The CPC for appropriate availability of procedures for an execution task is 0.8.
- CPC "Available Time": There is more than enough time to successfully perform this task. The CPC for adequate available time for an execution task is 0.5.
- CPC "Adequacy of Training/Preparation": This is a routine task that is clearly trained and emphasized in training. Because it is routine, there is a high level of experience. The CPC for adequate training and high experience for an execution task is 0.8.

Applying these factors yields the following:

$$\text{Operator fails to close port gate before lifting shield skirt} = 0.03 \times 0.8 \times 0.8 \times 0.5 \times 0.8 = 0.008$$

HEP Calculation for Scenario 4(a)—The events in the HEP model for Scenario 4(a) are presented in Table E6.4-16.

Table E6.4-16. HEP Model for HFE Group #4 Scenario 4(a) for 200-OpCTMDirExp1-HFI-NOD

Designator	Description	Probability
A	Worker violates administrative control by entering the Canister Transfer Room during canister transfer	0.0009
B	Operator fails to close port gate before lifting shield skirt	0.008

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

Source: Original

The Boolean expression for this scenario follows:

$$A \times B = 0.0009 \times 0.008 = 8E{-}06 \quad \text{(Eq. E-34)}$$

E6.4.3.4.5.2 HEP for HFE 200-OpCTMDirExp1-HFI-NOD

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

$$\text{060-OpCTMDirExp1-HFI-NOD} = \text{HEP 4(a)} = 8E{-}6 \quad \text{(Eq. E-35)}$$

E6.4.4 Results of Detailed HRA for HFE Group #4

The final HEPs for the HFEs that required detailed analysis in HFE Group #4 are presented in Table E6.4-17 (with the original preliminary value shown in parentheses).

Table E6.4-17. Summary of HFE Detailed Analysis in HFE Group #4

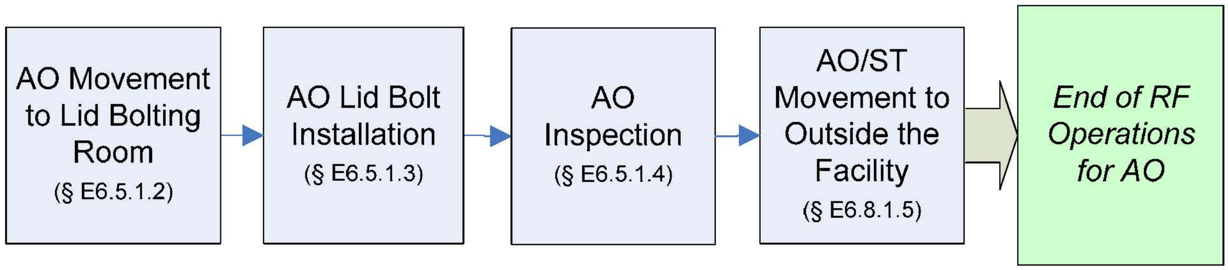
HFE	Description	Final Probability
200-OpCTMdrop001-HFI-COD	Operator causes drop of object onto canister during CTM operations	4E−7 (2E−03)
200-OpCTMdrop002-HFI-COD	Operator causes drop of canister during CTM operations (low-level drop)	5E−7 (2E−03)
	Applied to removing a DPC from a TC	5E−7 (2E−03)
	Applied to removing any other canister from a TC or any canister from an AO	5E−7 (2E−03)
200-OpCTMImpact1-HFI-COD	Operator moves the CTM while canister or object is below or between levels	4E−8 (1E−03)
200-OpCTMDirExp1-HFI-NOD	Direct exposure during CTM activities (Second Floor)	8E−6 (1E−4)

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

Source: Original

E6.5 ANALYSIS OF HUMAN FAILURE EVENT GROUP #5: CLOSURE AND EXPORT OF AGING OVERPACK

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 closure and export of aging overpacks. The operations covered in this HFE group are shown in Figure E6.5-1. The operations begin with the canister having been placed into the aging overpack by the CTM, the aging overpack still located below the cask port, and the cask port closed. It proceeds though the site transporter operator moving the aging overpack under the preparation platform in the preparation area from the loading room, the placing and bolting of the aging overpack lid onto the aging overpack, and the site transporter exporting the aging overpack from the RF via the Site Transporter Entrance Vestibule. It ends once the site transporter/aging overpack has exited the facility and the exterior entrance vestibule door is closed.



NOTE: § = Section; AO = aging overpack; RF = Receipt Facility; ST = site transporter.

Source: Original

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

E6.5.1 Group #5 Base Case Scenario

E6.5.1.1 Initial Conditions and Design Considerations Affecting the Analysis

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

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

2. The site transporter is off with forks lowered.

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

The following personnel are involved in this set of operations:

- Crew members (two people)
- Supervisor
- 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.

E6.5.1.2 Aging Overpack Movement to Lid Bolting Room

A crew member opens the Lid Bolting Room shield door, and the site transporter operator turns on the site transporter, raises the site transporter forks, and moves the loaded aging overpack out of the Cask Unloading Room to the Lid Bolting Room on the site transporter. The site transporter operator performs this task visually and also receives confirmatory hand signals from

[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.

the crew member. Once the site transporter is cleared out of the Cask Unloading Room, the crew member closes the shield door.

E6.5.1.3 Aging Overpack Lid Bolt Installation

Using the lid bolting platform, shield plate, and common tools, a crew member(s) closes the shield plate, emplaces and tightens all the aging overpack lid bolts according to the proper procedure, and then verifies on the checklist that all the bolts have been properly installed.

E6.5.1.4 Aging Overpack Inspection

Once the cask is ready to leave the facility, the crew conducts a visual inspection and radiological survey of the exterior of the cask.

E6.5.1.5 Aging Overpack Movement from Lid Bolting Room to Outside

Movement of Loaded Site Transporter out of Lid Bolting Room—Once the aging overpack lid bolts have been installed in the Lid Bolting Room, the overhead door to the vestibule **is** opened**,** and the site transporter carrying the aging overpack proceed**s** to the Site Transporter Vestibule and stops. The inside door (shield door) is then closed by a crew member. A checklist **is** signed to indicate that the inside door has been closed.

Movement of Loaded Site Transporter out of the Site Transporter Vestibule—Once the door to the Cask Preparation Room has been closed, a crew member open**s** the outside door of the Site Transporter Vestibule and the site transporter operator proceed**s** to move the site transporter to the outside. Once the site transporter has cleared the outside overhead door, a crew member closes the door.

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 closure and export of an aging overpack are summarized in Table E6.5-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
200-OpSTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of ST with SSC while Moving from the Cask Loading Room to the Lid Bolting Room*: The operator causes collision of ST with facility structure or equipment while moving the ST under the platform from the Cask Loading Room.	7	3E−03	The site transporter can collide into an SSC such as the facility door, an auxiliary vehicle, or improperly stowed crane rigging while in transit from the Loading Room to the Lid Bolting Room. Collision of a site transporter is a similar operation and has the same failure modes as the railcar collision HFE (200-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) but was adjusted because there are several ways for a collision to occur (×3).
200-OpImpact0000-HFI-NOD	*Operator Causes Impact of Cask during Transfer from Loading Room to Preparation Station*: While moving from the Cask Loading Room to the Lid Bolting Room, the ST can impact the crane hook or rigging if it is improperly stowed.	7	N/A	While moving from the Cask Loading Room to the preparation station in the Lid Bolting Room, the site transporter can impact the crane hook or rigging if it is improperly stowed. The shield plate is closed at the end of every operation involving the preparation platform. It is unlikely, then, that the crane rigging will be improperly stowed such that it can impact the site transporter while it is moving out of the Cask Loading Room; it is more likely that rigging will impact the cask while the crane is actually in use. Therefore, any crane interference with the site transporter is already covered by *200-OpAOImpact01-HFI-NOW* (Operator Causes Aging Overpack Impact during Aging Overpack Closure) and 200-OpTipover003-HFI-NOD (Operator Causes Tipover of Site Transporter) in this section. This failure is identical to Operator Causes Impact of Cask during Transfer from Preparation Station to Loading Room (200-OpImpact0000-HFI-NOD; Section E6.3, HFE Group #3).
200-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance*: Once the CTM activities are over, an operator opens the shield door, turns on the ST, lifts the forks, and moves the cask from the Cask Loading Room to the Lid Bolting Room. There is a shield door between the Cask Loading Room and the Lid Bolting Room. Also, while exporting the ST, the ST must pass through the door between the Lid Bolting Room and the ST Entrance Vestibule. The operator can impact the cask by inadvertently closing the shield door on the ST as the ST passes through the door.	5	1.0	The site transporter passes through a shield door as it moves from the Cask Unloading Room into the Lid Bolting Room. During this transfer, the operator can cause the site transporter to collide into the shield door or close the shield door on the site transporter. Section E6.0.2.3.3 provides a justification of this preliminary value.
200-OpCTCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of Auxiliary Vehicle with ST during Closure Activities*: While the ST is parked under the platform for closure activities, the operator of an auxiliary vehicle can collide into the ST. If the speed governor is functioning, this is a low-speed collision.	7	3E−03	In this step the site transporter is loaded and parked under the 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 Lid Bolting Room during cask operations. This HEP was assigned the same preliminary value as railcar collision HFE (*200-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 site transporter is staged under the platform, and the railcar/truck trailer collision HFE has additional failure modes associated with movement of the site prime mover that are not applicable here. This failure is identical for the preparation activities in a CTT (200-OpCTCollide1-HFI-NOD; Section E6.3, HFE Group #3). The justification is that this failure is "highly unlikely" (one in a thousand or 0.001) but was adjusted because there are several ways for a collision to occur (×3).
200-OpFLCollide1-HFI-NOD	*Operator Causes High-Speed Collision of ST with SSC*: The operator can cause an auxiliary vehicle to collide into a loaded ST while the conveyance is parked in the Lid Bolting Room. If the collision is due to the auxiliary vehicle speed governor malfunctioning, this is a high-speed collision.	7	1.0	The operator can cause an auxiliary vehicle (e.g., a forklift) to overspeed, 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 motor design from going too fast. To be conservative, unsafe actions that require an equipment failure to cause an initiating event have generally been assigned an HEP of 1.0.
200-OpTipOver003-HFI-NOD	*Operator Causes Tipover of ST*: If the operator improperly stows the crane rigging, it can catch the ST or aging overpack during AO closure. If the crane becomes attached to the ST or AO and the operator continues to move the ST (e.g., exiting the Lid Bolting Room) or crane, the ST could tip over.	7	1E−04	In this step the site transporter is moved from the preparation station to the Loading Room, the aging overpack lid bolts are removed, and then the site transporter is exported from the facility via the Site Transporter Entrance Vestibule. 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 closure activities is the crane attached to the aging overpack. The lid bolts may be installed 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 closure activities, it is unlikely that the crane operator does not notice while trying to move the crane. It is also unlikely that, when the site transporter is moving away from the platform, the site transporter operator and observers will not notice that the rigging has caught the site transporter because tipover is a slow process. This operation was given the same preliminary value as the Cask Tip Over During Uprighting and Removal HFE (200-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because it has the same dominant failure mode: crane rigging improperly stowed and 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 tipover in that scenario.

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

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
200-OpAOImpact01-HFI-NOW	*Operator Causes Impact of AO during AO Closure*: During AO closure the AO lid is bolted. If the lid bolts are installed with the crane, it is possible that the AO/ST can be impacted by the crane hook due to improper crane operations.	7	3E−03	In this step, the aging overpack lid bolts are installed. If the crane is used to move the lid bolts, it is possible that the crane can impact the side of the site transporter/aging overpack. 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 by 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) and was accordingly assigned the same preliminary value: this failure was assessed as "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 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 that makes it harder to impact the site transporter.
Drop of object on AO	*Operator Drops Heavy Object on AO during AO Closure*: During AO closure the AO lid is bolted. 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 closure activities simply entail installing the lid bolts. In this step the lid bolts or the tools used to install 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."
200-OpSpurMove01-HFI-NOD	*Operator Causes Spurious Movement of ST During Closure 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 AO closure, the operator can inadvertently cause the ST to move. This spurious movement can cause the ST to collide into the platform.	7	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 (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 turn off the site transporter, and an operator would have to access the pendent and signal the site transporter to move. This failure is identical to spurious movement of a CTT during Preparation Activities (200-OpSpurMove01-HFI-NOD; Section E6.3, HFE Group #3).
200-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 AO lid when bolts are installed, resulting in a direct exposure.	10	N/A	In this step the aging overpack lid is bolted with, perhaps, the use of the crane. Due to design changes to the preparation platform, improperly stowed rigging during this operation does not catch the lid lift fixture. These design changes include raising the platform and adding a shield plate so the cask is recessed underneath the platform and protected by the shield plate. Therefore this failure was omitted from analysis.
200-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 closure activities.	8	N/A	The aging overpack is not purposefully lifted in this step. 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 that holds the aging overpack raised 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 that 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 that it has not dropped in transit to the facility because the aging overpack is not removed from the site transporter in the RF. Also, there are interlocks that 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 the analysis.
200-OpSTCollide2-HFI-NOD	*Operator Causes Low-Speed Collision of ST with SSC while Exporting the ST*: The operator causes collision of the ST with a facility structure or equipment while moving through the Lid Bolting Room to the ST Vestibule and then outside the facility. This is a separate HFE from 200-OpSTCollide1-HFI-NOD because this movement of the ST is temporally separate from ST movement to the Lid Bolting Room. Movement is separated by lid bolting activities.	8	3E−03	The site transporter can collide into an SSC such as a facility door or improperly stowed crane rigging while in transit from the Lid Bolting Room to the Site Transporter Vestibule and then out of the facility. This failure is identical to the following failure in this section: 200-OpSTCollide1-HFI-NOD, Operator Causes Collision of Site Transporter During Movement from Transfer Room to Lid Bolting Room.
ST rollover	*Operator Causes ST to Roll over*: The operator drives over a significantly uneven surface while exporting the ST, causing the ST to roll over.	8	N/A	For a site transporter to roll over, the center of mass has to shift laterally. This can be done by traversing a significantly uneven surface or running over a very large object. There are no significantly uneven surfaces in the Site Transporter Vestibule/Lid Bolting Room; it is incredible for the site transporter to run over an object in the facility large enough to shift its center of mass.
200-OpFailStop-HFI-NOD	*Operator Fails to Stop ST if Tread Fails*: If the tread of the ST fails, it is possible the ST can roll over if the operator continues to operate the ST while trying to exit the facility.	8	1.0	If the tread of the site transporter fails, it is possible the site transporter can roll over 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.

NOTE: [a]HRA preliminary value replaced by use of historic data; Attachment C provides information about Active Component Reliability Data.
AO = aging overpack; CTM = canister transfer machine; ESD = event sequence diagram; HEP = human error probability; HFE = human failure event; ID = identification; N/A = not applicable; RF = Receipt Facility; SSC = structure, system, or component; ST = site transporter.

Source: Original

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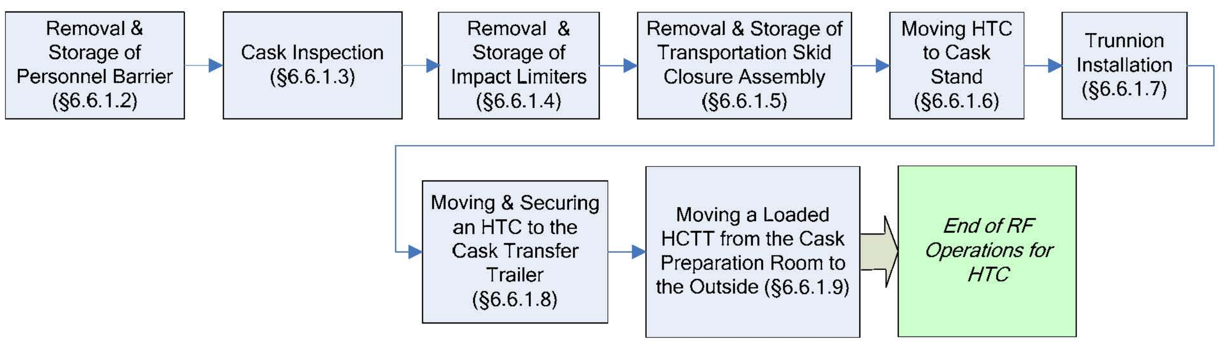
E6.5.3 Detailed Analysis

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 performance objectives of 10 CFR 63.111; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.6 ANALYSIS OF HUMAN FAILURE EVENT GROUP #6: EXPORT OF A DUAL-PURPOSE CANISTER IN A CASK TRACTOR AND CASK TRANSFER TRAILER

HFE group #6 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6-0.1, covering export of a transportation cask that is never upended (HTC) on a cask transfer trailer pulled by a cask tractor. The operations covered in this HFE group are shown in Figure E6.6-1. The activities covered in HFE group #6 begin with the HTC secure on a railcar in the Cask Preparation Area. In this operation, the HTC has its impact limiters removed and has trunnions installed. The HTC is then moved onto a cask transfer trailer and exported from the RF.



NOTE: § = section; HFE = human failure event; HTC = a transportation cask that is never upended; HCTT = cask tractor and cask transfer trailer; RF = Receipt Facility.

Source: Original

Figure E6.6-1. Activities Associated with HFE Group #6

E6.6.1 Group #6 Base Case Scenario

E6.6.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #6 activities:

1. The railcar is parked in the preparation area with its brakes set; the HTC is secure in the railcar.
2. The HCTT are staged in the preparation area with the brakes set and the cask tractor turned off, ready to be loaded with an HTC.
3. The cask stand is staged in the preparation area.

4. The cask handling crane (200-ton crane with 20-ton auxiliary hook) has the following safety features:

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

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

   C. There are speed limiters built into the motors.

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

   E. There is a temperature interlock that cuts off power to the crane 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 activity are not part of a specific procedure outlined in the YMP documentation, but rather reflect critical lift crane operations that are standard in the nuclear industry.

The following equipment is available for upending and transferring the cask:

1. Crane

   A. 200-ton cask handling crane
   B. 20-ton auxiliary hook.

2. Lift fixtures

   A. Impact limiter lifting device (uneven slings)
   B. Personnel barrier lifting device (sling)
   C. Cask sling (horizontal lifting beam).

3. Common tools and platform.

The following personnel are involved in this set of operations:

- Crane operator
- Signaling crew member
- Verification crew member
- Crew members (two)

- Radiation protection worker[12]
- Supervisor
- HCTT operator.

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

E6.6.1.2 Removal and Storage of Personnel Barrier (if required)

Most personnel barriers are removed at the geologic repository operations area entrance; however, this facility retains the capacity to remove personnel barriers if necessary. In order to remove the personnel barrier from the transportation cask, the crew members must first unbolt the barrier from the cask. The crane operator retrieves the crane and removes the personnel barriers as follows:

Alignment of Crane to Personnel Barrier—The crane operator lowers the 20-ton auxiliary crane into position over the personnel barrier. The operator is positioned on the floor in view of the crew members on either side of the personnel barrier. A signaling crew member next to the personnel barrier uses hand signals to guide the crane operator (no hardwired or wireless communication system is used). A verification crew member on the opposite side of the personnel barrier checks the alignment of the crane. The verification crew member can only signal to stop the crane. Once positioned, a crew member connects the crane to the personnel barrier using the personnel barrier lifting device, which is expected to be a sling. In order to use a sling, a crew member must secure the sling around the personnel barrier, attach the sling to the crane, and ensure that, when lifted, the load is level. If the sling is not positioned and the load is not level, the signaling crew member signals the crane operator to stop and lower the personnel barrier so that the sling can be repositioned.

Vertical Lifting of the Personnel Barrier—Upon signal from the signaling crew member that all is well, the crane operator begins to raise the personnel barrier. Once the personnel barrier has been raised (i.e., is hanging free) to the proper height (based on visual inspection), the crane operator stops raising the personnel barrier. The crane operator clears the railcar/truck trailer and then lowers the personnel barrier to the movement height. This action is confirmed by hand signals from the signaling crew member. The proper height for movement is roughly 6 in. above the highest obstacle in the movement path.

Movement of Personnel Barrier to Staging Location—The crane operator moves the 20-ton auxiliary crane to locate the personnel barrier over the position where it is lowered in the staging area, following the indicated safe load path marked on the floor. The crane operator performs this task visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

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

Lowering of Personnel Barrier and Disengagement of the Sling—When properly positioned in the staging area and the placement area is clear, the signaling crew member signals the crane operator to lower the personnel barrier. The crane operator then proceeds to lower the personnel barrier at or below the maximum allowable speed. Once the personnel barrier is stable on the floor of staging area, a crew member disengages the sling and the crane operator lifts the crane in preparation for the next operation.

E6.6.1.3 Cask Inspection

Once the conveyance is parked in the facility and the personnel barriers have been removed, the crew visually inspects and conducts radiological surveys of the exterior of the cask.

E6.6.1.4 Removal and Storage of Impact Limiters

This section describes the removal and staging of impact limiters using the 20-ton auxiliary crane with standard rigging, common tools, and the MAP. This step is performed twice, as each cask has two impact limiters.

Crew members, working with the crane operator, attach the impact limiter lifting device (uneven slings) to the 20-ton auxiliary crane.

After the personnel barrier is removed and the cask is inspected, the crew removes and stores the impact limiters. This operation is performed on the conveyance with training and procedures. The first step is to remove the restraining bolts on the impact limiters. Depending on the cask type, there can be anywhere from 24 to 36 bolts to remove, with several crew members removing the bolts simultaneously. Once removed, the bolts are counted, and the crew supervisor uses a checklist to verify and document bolt removal. Once bolt removal is verified, the crane operator removes and stores the impact limiters using the 20-ton auxiliary hook on the cask handling crane as follows:

Movement of Crane to Impact Limiter Position—The crane operator positions the crane over the impact limiter, following the indicated safe load path marked on the floor. The crane operator performs this task visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Alignment of Crane to Impact Limiter—The crane operator lowers the crane into position over the impact limiter. The crane operator is positioned on the floor in view of the crew members on either side of the impact limiter. A signaling crew member, next to the impact limiter, uses hand signals to guide the movement of the crane operator (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the impact limiter, checking alignment of the crane. The verification crew member can only signal the crane operator to stop. Once positioned, a crew member connects the crane to the impact limiter using the uneven sling and integral lift points.

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

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

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

E6.6.1.5 Removal and Storage of Transportation Skid Closure Assembly

The cask handling crane auxiliary hoist with standard rigging is used to lift the transportation cask skid closure assembly and place it in staging.

E6.6.1.6 Movement of HTC to Cask Stand

The HTC with impact limiters is moved to the cask stand using the 200-ton cask handling crane with cask sling.

The preparation for this step includes positioning the cask stand in the appropriate place (pre-staged), removing the rigging used to move the skid closure assembly, and attaching the cask sling to the crane.

Crane Movement to the HTC—The crane operator moves the 200-ton cask handling crane so as to locate the crane over the HTC, following the indicated safe load path marked on the floor. The operator does this visually and also receives confirmatory hand signals from the signaling crew member. The crane operator can roughly align the crane, but final alignment is directed by the signaling crew member.