Table E6.6-9. HEP Model for HFE Group #6 Scenario 2(a) for 050-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/hoist 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 follows:

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

E6.6.3.4.3.2 HFE Group #6 Scenario 2(b) for 050-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.

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 has engaged. If the operator sees that the grapple has not properly engaged (generally by checking the interlock condition if it looks engaged visually), then the operator disengages it, repositions the grapple, and tries again to engage.

The operator aligns the grapple visually using the view from the camera and 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 affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The crew member probably feels a little more time pressure than that, so the APOA 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 affect 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 the camera view is deemed to represent full effect. The APOA is set at 1.0.

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

Using the NARA HEP equation yields 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 E6.6.3.4.1.

Grapple engagement interlock gives false positive signal = 2.7E−5

Operator Fails to Notice Grapple Not Fully Engaged through Camera—As the lift begins, the operator is supposed to watch through the cameras. This allows 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 case, the operator's check is a self-check; again, the operator is checking the actions taken 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 the false positive 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

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

This event is quantified in Section E6.6.3.4.1.

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 E6.6-10.

Table E6.6-10. HEP Model for HFE Group #6 Scenario 2(b) for 050-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:

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

E6.6.3.4.3.3 HFE Group #6 Scenario 2(c) for 050-OpCTMdrop002-HFI-COD (Applies to DPC/Transportation Cask 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 transportation cask/DPCs because the transportation cask lid was removed in the preparation 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 transportation 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 more than 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:

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

Operator Fails to Notice that 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 that the hoist has to be moved to be in position. Possible inappropriate responses include: (1) the initial placement of the bell is in question and it is repositioned (which may be easier to accomplish than asking another crew member to move the CTT), or (2) a belief that the position of the CTT is not off center by enough to make a difference.

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 error (the operator cannot help but observe the relative locations of the grapple and the lid) or a diagnosis error (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 plenty of 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 = $0.01 \times 5 = 0.05$

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 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 E6.6.3.4.1.

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 E6.6.3.4.1.

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 E6.6-11.

Table E6.6-11. HEP Model for HFE Group #6 Scenario 2(c) for 050-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:

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

E6.6.3.4.3.4 HEP for HFE 050-OpCTMdrop002-HFI-COD

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

$$\text{050-OpCTMdrop002-HFI-COD (DPC/transportation cask)} = \text{HFE 2(a)} + \text{HFE 2(b)} + \text{HFE 2(c)} = (<1\text{E}{-8}) + 5\text{E}{-7} + (<1\text{E}{-8}) = 5\text{E}{-7} \qquad \text{(Eq. E-23)}$$

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

$$\text{050-OpCTMdrop002-HFI-COD (non-DPC/transportation cask)} = \text{HFE 2(a)} + \text{HFE 2(b)} = (<1\text{E}{-8}) + 5\text{E}{-7} = 5\text{E}{-7} \qquad \text{(Eq. E-24)}$$

E6.6.3.4.4 Quantification of HFE Scenarios for 050-OpCTMImpact1-HFI-COD: Operator Moves the CTM while Canister or Object Is below or between Levels

E6.6.3.4.4.1 HFE Group #6 Scenario 3(a) for 050-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in lid lift mode (nontransportation cask/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 Leaves CTM in Lid Lift Mode (Nontransportation Cask/DPCs)—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 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:

Operator fails to notice lift is taking too long = 0.2 × 0.8 × 0.5 × 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:

Operator fails to close port slide gate = 0.03 × 0.5 × 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 time signifies 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 affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOA is set at 0.1.

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

Using the NARA HEP equation yields the following:

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

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 in 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 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 Table 20-21, the HEP follows:

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 (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 E6.6.3.4.1.

$$\text{CTM slide gate interlock fails} = 2.7\text{E}{-5}$$

HEP Calculation for Scenario 3(a)—The events in the HEP model for Scenario 3(a) are presented in Table E6.6-12.

Table E6.6-12. HEP Model for HFE Group #6 Scenario 3(a) for 050-OpCTMImpact1-HFI-COD

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:

$$\begin{gathered} A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.0007 \times 0.07 \\ \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7\text{E}{-05} = \\ 0.0007 \times 0.07 \times 0.006 \times 2.7\text{E}{-05} = (<1\text{E}{-8}) \end{gathered} \tag{Eq. E-26}$$

E6.6.3.4.4.2 HFE Group #6 Scenario 3(b) for 050-OpCTMImpact1-HFI-COD

1. Operator places CTM in lid lift mode (transportation cask/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 transportation cask/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.

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. For the situation involving transportation cask/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 CPC:

- 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, 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 the suspicion 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 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:

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 would be 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:

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

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

Using the NARA HEP equation yields the following:

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

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. 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 in 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 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 Table 20-21, the HEP follows:

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 (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 E6.6.3.4.1.

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 E6.6-13.

Table E6.6-13. HEP Model for HFE Group #6 Scenario 3(b) for 050-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:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.005 \times 0.07 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7\text{E}{-05} = 0.005 \times 0.07 \times 0.006 \times 2.7\text{E}{-05} = (<1\text{E}{-8}) \quad \text{(Eq. E-28)}$$

E6.6.3.4.4.3 HFE Group #6 Scenario 3(c) for 050-OpCTMImpact1-HFI-COD

1. Operator puts CTM in maintenance mode (nontransportation cask/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 puts CTM in maintenance mode (Nontransportation cask/DPCs). 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 allows 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, since 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 still can override the feature and enter manual mode. The full affect is ×9. The APOA anchor for 0.5 is for something overridden on a regular basis. The APOA anchor for 0.1 is for something overridden once in a while. Other considerations for a reduction from full affect 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 APOA 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 (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 CTM 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 would be in 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 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 in 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 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 E6.6.3.4.1.

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 E6.6-14.

Table E6.6-14. HEP Model for HFE Group #6 Scenario 3(c) for 050-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:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.0004 \times 0.003 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 0.0004 \times 0.003 \times .006 \times 2.7E{-}05 = 7E{-}09 \times 2.7E{-}05 = (<1E{-}08) \quad \text{(Eq. E-30)}$$

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

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

E6.6.3.4.4.4 HFE Group #6 Scenario 3(d) for 050-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in maintenance mode (transportation cask/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 (transportation cask/DPCs)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. For transportation cask/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, 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—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator the 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 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 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. This 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 in 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 E6.6.3.4.1.

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 E6.6-15.

Table E6.6-15. HEP Model for HFE Group #6 Scenario 3(d) for 050-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:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G =$$
$$0.0007 \times 0.003 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 =$$
$$0.0004 \times 0.003 \times 0.006 \times 2.7E{-}05 = 7E{-}09 \times 2.7E{-}05 = (<1E{-}08) \qquad \text{(Eq. E-32)}$$

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

$$1E{-}5 \times 2.7E{-}5 = (<1E{-}08) \qquad \text{(Eq. E-33)}$$

E6.6.3.4.4.5 HEP for HFE 050-OpCTMImpact1-HFI-COD

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

$$\text{050-OpCTMImpact1-HFI-COD} = \text{HFE 3(a)} + \text{HFE 3(b)} + \text{HFE 3(c)} +$$
$$\text{HFE 3(d)} = (<1E{-}8) + (<1E{-}8) + (<1E{-}8) + (<1E{-}8) = 4E{-}8 \qquad \text{(Eq. E-34)}$$

NOTE: For lifting objects (STC 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.

E6.6.3.4.5 Quantification of HFE Scenarios for 050-OPCTMDirExp1-HFI-NOD: Operator Causes Direct Exposure during CTM Activities (Second Floor)

E6.6.3.4.5.1 HFE Group #6 Scenario 4(a) for 050-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 that 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 APOA 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:

$$\text{Worker violates administrative control by entering the Canister Transfer Room during canister transfer} = 0.0001 \times [(9-1) \times 1.0 + 1] = 0.0009 \quad \text{(Eq. E-35)}$$

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., aging overpack, STC), 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:

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 E6.6-16.

Table E6.6-16. HEP Model for HFE Group #6 Scenario 4(a) for 050-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:

$$A \times B = 0.0009 \times 0.008 = 8E{-}06 \quad \text{(Eq. E-36)}$$

E6.6.3.4.5.2 HEP for HFE 050-OpCTMDirExp1-HFI-NOD

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

$$\text{050-OpCTMDirExp1-HFI-NOD} = \text{HEP } 4(a) = 8E{-}6 \quad \text{(Eq. E-37)}$$

E6.6.4 Results of Detailed HRA for HFE Group #6

The final HEPs for the HFEs that required detailed analysis in HFE Group #6 are presented in Table E6.6-17 (with the original preliminary value shown in parentheses):

Table E6.6-17. Summary of HFE Detailed Analysis for HFE Group #6

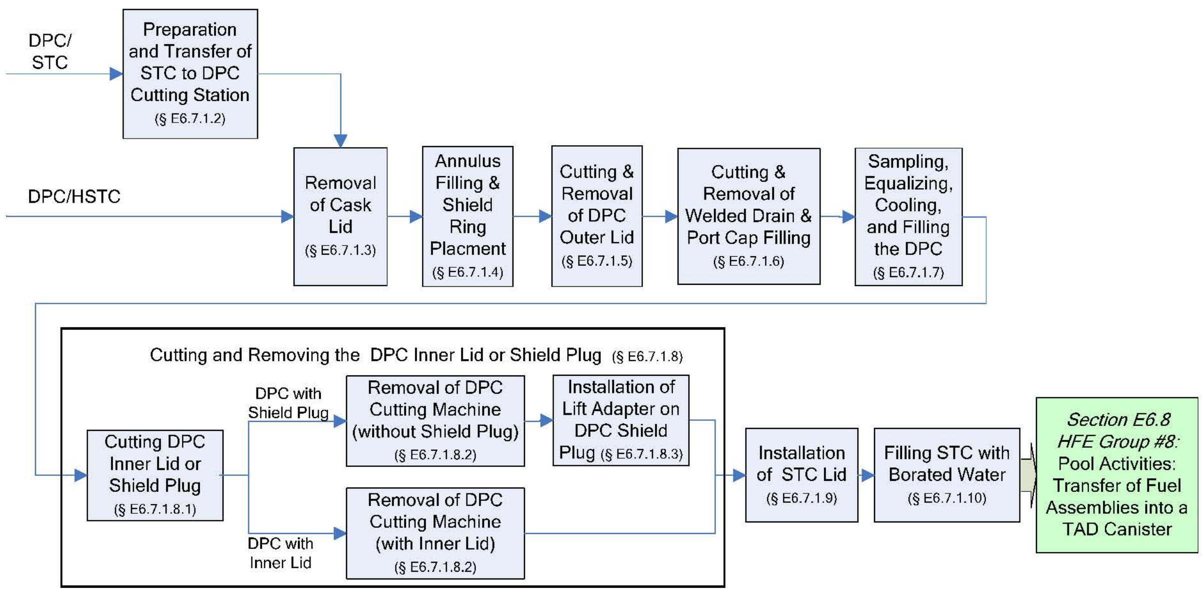
HFE	Description	Final Probability
050-OpCTMdrop001-HFI-COD	Operator causes drop of object onto canister during CTM operations	4E−7 (2E−03)
050-OpCTMdrop002-HFI-COD	Operator causes drop of canister during CTM operations (low level drop)	5E−7 (2E−03)
	Applied to removing a DPC from a TC	5E−7 (2E−03)
	Applied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

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

Source: Original

E6.7 ANALYSIS OF HUMAN FAILURE EVENT GROUP #7: DPC CUTTING

HFE group #7 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering DPC cutting. There are two variations on this step: (1) a DPC in an STC (Section E6.6) is moved to the DPC cutting station from the Cask Unloading Room and is opened, and (2) a DPC in an HSTC (Section E6.2) is already at the DPC cutting station and is opened. For a DPC in an STC this operation begins with the CTT, loaded with a STC/DPC, in the Cask Unloading Room. The STC/DPC is moved to the preparation platform where the lid is bolted. The STC/DPC is then moved with the cask handling crane to the DPC cutting station. From this point on the HSTC/DPC, which is already at the DPC cutting station, and STC/DPC are handled in the same manner. The DPC is sampled, cooled, and filled with borated water and then the DPC lid is removed. The operation ends with the open DPC sitting in the DPC cutting station with STC lid bolted on, ready for transport into the pool. Figure E6.7-1 provides an overview of the operations in HFE group #7.



NOTE: § = Section; DPC = dual-purpose canister; HSTC = horizontal shielded transfer cask; HFE = human failure event; STC = shielded transfer cask; TAD = transportation, aging, and disposal.

Source: Original

Figure E6.7-1. Activities Associated with HFE Group #7

E6.7.1 Group #7 Base Case Scenario

E6.7.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #7 activities:

1. The STC with DPC is secured to the CTT and is positioned in the Cask Unloading Room. The STC has a lid on, is unbolted, and the DPC lifting device is still attached to the DPC.

2. The HSTC with DPC is sitting in the DPC cutting station with lid bolted on and no DPC lifting device attached to the DPC.
3. There is an interlock between the port slide gates and the Cask Unloading Room shield door. The port slide gate cannot be opened while the shield door to the Cask Unloading Room is also open.
4. The CTT is an air-pallet apparatus that is guided by two removable rails. The CTT also has end stops to aid in final positioning. A safe load path is marked for the CTT operations, and there are at least three crew members involved in its movement when loaded.
5. The cask handling crane (200-ton) is in the Cask Preparation Area and has the following safety features:
   A. Upper limits—There are two upper limit marks: the initial is an indicator, and the final (which is set higher than the upper limit indicator) cuts off the power to the hoist. There is no bypass for the final limit interlock.
   B. There are end-of-travel interlocks on the trolley and bridge.
   C. There are speed limiters built into the motors.
   D. There is a weight interlock that cuts off power to the crane when the crane capacity is exceeded.
   E. There is a temperature interlock that cuts off power to the hoist when the temperature is too high. An indicator comes on before this temperature is reached.
   F. There is an indicator to signal the operators that the cask handling yoke is fully engaged, and an interlock (yoke engagement) that prevents the crane from moving unless and the yoke is either fully engaged or disengaged.
6. The jib crane at the DPC cutting station and the jib crane at the preparation station are expected to have the same safety features as the cask handling crane with the exception of the yoke interlock.

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

The following personnel are involved in this set of operations:

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

- Radiation protection worker[13]
- Supervisor
- DPC cutter
- CTT operator.

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

E6.7.1.2 Preparation and Transfer of STC to DPC Cutting Station

This step is only applicable to DPCs in an STC coming from the Cask Unloading Room (not HSTCs).

E6.7.1.2.1 Movement of an STC to Preparation Station in Cask Preparation Area

After a DPC has been transferred into the STC in the Cask Unloading Room, the Cask Unloading Room door is opened and the CTT operator moves the CTT, loaded with an STC/DPC to the Cask Preparation Area. The Cask Unloading Room door is then closed.

E6.7.1.2.2 Removal and Storage of STC Lid on Lid Rack

Once the cask is in place under the platform, the crew opens the shield plate and removes the STC lid using the jib crane and standard rigging.

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

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

Lid Moved to Staging Area—Using the jib crane, the crane operator positions the lid over the lid stand in the staging area. The crane follows the indicated safe load path marked on the floor visually, with confirmatory hand signals from the signaling crew member. The crane operator then sets down the lid and disengages the hook.

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

E6.7.1.2.3 Removal of DPC Lift Fixture

The DPC lift fixture is removed from the DPC using the jib crane with grapple or hook, cask preparation platform, and common tools. The crane operator and the signaling and verification crew members are positioned on the cask preparation platform for this step.

DPC Lift Fixture Unbolting—A crew member closes the shield plate and uses the cask preparation platform and common tools to unbolt and remove all the lid fixture bolts according to training and then verifies (using a checklist) that all the bolts have been properly removed. Once the checklist has been marked off, the shield plate operator opens the shield plate in preparation for the next step.

Movement of Crane to Cask—The crane operator positions the jib crane over the cask/DPC fixture in the Cask Preparation Area. The crane operator visually follows the indicated safe load path marked on the floor, with confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member that can (hand) signal the crane operator to stop at anytime. At this time, the shield plate crew member opens the shield plate to allow the fixture to be positioned. The crane operator can roughly align the fixture over the DPC, but final alignment is directed by the signaling crew member.

Lowering and Engaging Lift Fixture—When properly positioned over the DPC, the signaling crew member signals the crane operator to lower the crane into place. The crane operator then proceeds to lower the crane at or below the maximum allowable speed. Once the crane is in place, the crane operator engages the DPC lift fixture, lifts the crane to operational height, and moves the lift fixture to the staging area. The crane operator and crew stay several feet away from the platform while the shield plate is open. The crew then closes the shield plate.

E6.7.1.2.4 Installation of STC Lid

Retrieval and Movement of STC Lid to Cask – The crane operator positions the jib crane hook over the STC lid. The crane operator engages the hoist to the lid, lifts the lid vertically to the proper operational height, and moves the lid to the cask following a safe load path based on visual inspection and with confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the lid over the cask, but final alignment is directed by the signaling crew member. Once aligned, a crew member opens the shield plate.

Lid Placement—Once the shield plate has been opened and the lid is properly aligned, the crane operator lowers the STC lid, disengages the hook/grapple, and retracts the hoist to the maximum height for the next crane operation.

Lid Bolting—With the lid in place, the crew closes the shield plate and, using long-reach tools, bolts the lid onto the STC. Before moving the cask, a checklist is used to ensure that at least four bolts have been used to secure the lid.

E6.7.1.2.5 Release of STC from CTT

The STC is released from the CTT by personnel using common tools. This is done on the preparation platform in the Cask Preparation Area.

E6.7.1.2.6 Movement of STC to DPC Cutting Station

The STC is moved from the CTT to the DPC cutting station using the 200-ton cask handling crane with the cask handling yoke.

Movement of Crane to STC—The operator positions the 200-ton crane over the STC. The crane operator visually follows the indicated safe load path marked on the floor, with confirmatory hand signals from the signaling crew member. The operator can roughly align the crane, but final alignment is directed by the signaling crew member.

Aligning the Crane to the Cask—The crane operator lowers the 200-ton crane into position so that the yoke arms are lined up with the trunnions. The operator is positioned on the floor in view of the crew members on either side of the cask. There is a signaling crew member next to the cask who uses hand signals to guide the crane operator’s movements (no hardwired or wireless communication system is used). There is a verification crew member on the opposite side of the cask checking alignment of the second trunnion; the verification crew member can only signal the crane operator to stop.

Engagement of Yoke Arms on Trunnions—Once the yoke is aligned, the signaling crew member signals the operator to close the yoke arms. The crew members check to see that the yoke arms have attained at least the minimum amount of engagement (minimum distance from edge of trunnion to edge of yoke arm). If the arms are sufficiently engaged on both sides, the crane operator knows by an indicator on the controller and the signaling crew member signals the operator to raise the crane a slight amount to put pressure on the arms. The crane operator sees on the controller that the 200-ton crane is bearing weight. Both crew members verify that the yoke remains level. If the arms do not engage on the initial attempt either crew member can signal the operator to stop, and the crane operator then sets the cask down and opens the yoke arms to disengage them from the cask. The signaling crew member directs the movement of the crane with hand signals, and then once aligned, signals the operator to close the yoke arms.

Movement of Cask to DPC Cutting Station—The crane operator raises the cask, clears the CTT, and then lowers the cask to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The crane operator confirms the height visually and obtains confirmation from the signaling crew member before beginning movement to the DPC cutting station. The operator visually follows the indicated safe load path marked on the floor, with confirmatory hand signals from the signaling crew member. There is a verification crew member on the opposite side of the cask from the signaling crew member who is the only one authorized to give the crane operator a signal to stop. The operator can roughly align the cask with the DPC cutting station, but final alignment is directed by the crew member, since the operator's view of the alignment with the platform may be obstructed. Once properly positioned, the crew member signals the crane operator to lower the cask. The crane operator then disengages the yoke, lifts the crane to the proper height for movement, and moves it to the yoke stand.

E6.7.1.3 Removal of Cask Lid (All Variations)

E6.7.1.3.1 Removal of Lid Bolts

The crew uses the DPC cutting station platform and common tools to unbolt the cask lid. The bolts are removed, counted, and verified on a checklist.

E6.7.1.3.2 Removal and Storage of Cask Lid

From the second floor of the DPC cutting station, the crane operator removes the STC lid using the jib crane with grapple and stages it on the lid stand.

Lid Removal—The crane operator lowers the jib crane into position over the lid and engages the grapple. Once engaged properly (indicator), the crane operator lifts the lid and clears the cask, then lowers the lid to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path) based on a visual inspection and confirmation by the signaling crew member via hand signals.

Movement of Lid to Lid Stand—The crane operator moves the jib crane to the lid stand following the safe load path indicated on the floor. The operator does this visually, and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator then places the lid on the lid stand and disengages the grapple.

E6.7.1.4 Annulus Filling and Shield Ring Placement

E6.7.1.4.1 Fill Annulus with Borated Water

The crew attaches two hoses to the STC (one to the vent port and one to the fill port) via the quick disconnect ports. The other ends of the hoses are in the pool with filters attached. The crew turns on a pump to fill the annulus between the DPC and the STC with borated water. Once the annulus is full, a crew member turns off the pump, disconnects the hoses, and closes the ports. The annulus is full when there are no bubbles coming out of the return line in the pool.

E6.7.1.4.2 Placement of the Shield Ring between the DPC Canister and the STC

From the DPC cutting platform, the crane operator retrieves the shield ring using a jib crane with standard rigging, and places it over the DPC canister.

Retrieval of Shield Ring—The crane operator remotely lowers the jib crane into position over the shield ring in the staging area and attaches the slings. Once the slings are attached, the signaling crew member signals the crane operator to slightly lift the shield ring. The crew members then check to see that the shield ring is balanced on the sling and that the sling is properly engaged. Both crew members verify that the shield ring remains level and the crane operator lifts the shield ring to the proper height for movement (i.e., roughly 6 in. above the highest obstacle in the movement path). The crane operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals.

Movement of Shield Ring to Cask—Using the jib crane, the crane operator positions the shield ring over the cask. The operator does this based on visual inspection and also receives confirmatory hand signals from the signaling crew member. There is also a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the shield ring over the cask, but final alignment is directed by the signaling crew member.

Lowering the Shield Ring and Disengaging the Sling—When properly positioned, the signaling crew member signals the crane operator to lower the shield ring into place. The crane operator then proceeds to lower the shield ring at or below the maximum allowable speed. Once the shield ring is in place, the crew member disengages the sling from the shield ring.

E6.7.1.5 Cutting and Removal of DPC Outer Lid

E6.7.1.5.1 Attachment of DPC Cutting Machine to DPC

The crane operator uses the DPC cutting platform, common tools, and the jib crane with hook to retrieve and emplace the adapter plate and cutting machine. Once in place, the crew members attach the adapter plate to the DPC with bolts. This step is verified with a checklist.

Attach DPC Cutting Machine to Adapter Plate—The crane operator and crew members use the jib crane with standard rigging to move the DPC cutting machine from its staging area to the adapter plate staging area. The crew uses common tools to bolt the DPC cutting machine to the adapter plate, without detaching the crane from the DPC cutting machine. This step is verified with a check list.

Retrieval of Adapter Plate/Cutting Machine—The jib crane is attached to the DPC cutting machine, which is bolted to the adapter plate. The crane operator lifts the adapter plate/cutting machine to proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals.

Movement of the Adapter Plate/Cutting Machine to the DPC— Using the jib crane, the crane operator positions the adapter plate over the DPC in the DPC cutting station, 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. There is also a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the adapter plate over the cask, but final alignment is directed by the signaling crew member.

Lowering the Adapter Plate/Cutting Machine and Disengaging the Crane—When properly positioned over the cask, the signaling crew member signals the crane operator to lower the adapter plate into place. The crane operator then proceeds to lower the adapter plate at or below the maximum allowable speed. Once the adapter plate is in place, the crew member disengages the hoist and the crane lifts to its maximum height in preparation for the next operation.

A crew member uses the cask preparation platform and common tools to emplace and tighten all the adapter plate bolts according to training and then verifies (checklist) all the bolts have been properly installed.

E6.7.1.5.2 Cutting of DPC Outer Lid with DPC Cutter

The operator is on the platform and uses a camera for this operation. Once the DPC cutting machine is securely in place on the DPC, the operator starts the cutting machine and cuts the outer lid weld. The cutting machine is semi automated and cannot damage the canister.

E6.7.1.5.3 Removal of DPC Cutting Machine/Adapter Plate/Outer Lid

From the second floor of the DPC cutting station, the crane operator removes the DPC cutting machine, adapter plate and outer lid using the jib crane with hook, and stages it on the cutting machine stand.

The crane operator lowers the jib crane into position over the cutting machine and engages the hook with the cutting machine. Once engaged properly, the crane operator lifts the cutting machine (that is still attached to the adapter plate and outer lid) and clears the cask; the cutting machine is then lowered to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals. The crane operator moves the jib crane to the staging area, following the safe load path indicated on the floor. The operator does this visually, and also receives confirmatory hand signals from the signaling crew member. There is also a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator then places the cutting machine with outer lid on the outer lid stand.

Once the cutting machine/adapter plate/outer lid unit has been removed from the DPC and placed in the staging area, without disengaging the cutting machine from the crane, a crew member uses common tools to unbolt the adapter plate (with cutting machine) from the outer lid.

E6.7.1.6 Cutting and Removal of Welded Drain and Port Cap Filling

E6.7.1.6.1 Reinstallation of Adapter Plate/Cutting Machine on DPC Inner Lid

The crane operator uses the cask preparation platform, common tools, and the jib crane with hook to emplace the adapter plate/cutting machine. Once in place, the crew members attach the adapter plate to the DPC inner lid/shield plug with bolts. This step is verified with a checklist.

Retrieval of Adapter Plate/Cutting Machine—The crane is already attached to the lid adapter. The crane operator lifts the adapter plate to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals.

Movement of the Adapter Plate/Cutting Machine to DPC—Using the jib crane, the crane operator positions the adapter plate over the DPC in the DPC cutting station, 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. There is also a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the adapter plate over the cask, but final alignment is directed by the signaling crew member.

Lowering the Adapter Plate/Cutting Machine and Disengaging the Crane—When the adapter plate/cutting machine is properly positioned over the DPC, the signaling crew member signals the crane operator to lower the adapter plate into place. The crane operator lowers the adapter plate at or below the maximum allowable speed. Once the adapter plate is in place on the DPC inner lid, the crew member disengages the hook and the lifts the crane to its maximum height in preparation for the next operation.

A crew member uses the cask preparation platform and common tools to emplace and tighten all the adapter plate bolts (according to training), and verifies (using a checklist) that all the bolts have been properly installed.

E6.7.1.6.2 Cutting and Removal of Welded Cap over Drain and Filling Lines

The operator is on the platform and has to use a camera to perform this operation. Once the DPC cutting machine is in place on the DPC inner lid/shield plug, the operator starts the machine and cuts the welded cap over the DPC drain and fill lines. The crew then removes the cap using common tools. The cutting machine is semi automated and cannot damage the canister.

E6.7.1.7 Sampling, Equalizing, Cooling, and Filling the DPC

To sample the DPC, a crew member must plug a hose into the quick-disconnect drain port to start flow. Once connected, a crew member takes a reading of the gas that is being removed and verifies that the DPC is safe for opening. After the sample is taken, the remainder of the gas is vented, the valve is closed, and the hose taken off. If the DPC needs cooling, it is also cooled.

To fill/flush the DPC, the crew attaches two hoses to the DPC (one to the drain port and one to the fill port) via the quick disconnect ports. The other ends of the hoses are in the pool with filters attached. The DPC is then filled with borated waster until bubbles are no longer coming out of the return line. The pump is subsequently turned off, the valves are closed, and the hoses are disconnected. Continuous filling and flushing of the DPC may be necessary, in which case, a crew member would turn on a pump to cycle borated water through the DPC while the inner lid weld is being cut.

E6.7.1.8 Cutting and Removing Inner Lid or Shield Plug

E6.7.1.8.1 Cutting DPC Inner Lid or Shield Plug

The operator is on the platform and has to use a camera to perform this operation. Once the DPC cutting machine is in place on the DPC, the operator starts the machine and cuts the inner lid or shield plug weld. It takes several cycles of the cutting machine to cut through the weld. The cutting machine is semi automated and cannot damage the canister.

Just prior the final cutting cycle, the crew stops the cutting machine and stops cycling water through the DPC. The crew turns off the pump, lets the hoses drain back into the pool, disconnects the hoses, and closes the valves. The crew then restarts the cutting machine. The cutting crew member determines it is time to stop the cutting machine based on visual inspection (via camera) of the cut depth.

E6.7.1.8.2 Removal of the DPC Cutting Machine

From the second floor of the DPC cutting station, the crane operator removes the DPC cutting machine using the jib crane with hook, and stages it on the cutting machine stand. There are two variations of this step: (1) remove the DPC cutting machine with inner lid attached, and (2) disconnect the shield plug from the DPC cutting machine and then remove the DPC cutting machine only.

If the DPC has a shield plug, then a crew member unbolts the adapter plate/cutting machine unit from the shield plug and then removes the adapter plate/cutting machine unit only; if the DPC has an inner lid, the crew removes the adapter plate/cutting machine unit with the inner lid attached. To remove the cutting machine unit, the crane operator lowers the jib crane into position over the cutting machine and engages the hook. Once engaged properly, the crane operator lifts the cutting machine and clears the cask, then lowers the machine to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals. The crane operator moves the jib crane to the inner lid stand (if the inner lid is attached) or the cutting machine stand (if there is a shield plug) following the safe load path indicated on the floor. The operator does this visually, and also receives confirmatory hand signals from the signaling crew member.

E6.7.1.8.3 Installation of Lift Adapter on DPC Shield Plug (DPC with shield plug only)

For DPCs with shield plugs, the crane operator uses the jib crane and standard rigging to retrieve the shield plug lift adapter from the staging area and move to the DPC. Once the shield plug adapter is put in place on the shield plug, the crew uses the platform and common tools to bolt the adapter to the shield plug. The shield plug is removed in the pool, but the lift adapter is installed on the platform.

Retrieval and Movement of Lift Adapter to the DPC—Following the indicated safe load path marked on the floor, the crane operator uses the jib crane to retrieve the shield plug lift adapter and position the adapter over the DPC shield plug in the DPC cutting station. The operator does this visually, and also receives confirmatory hand signals from the signaling crew member. There is also a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the adapter over the cask, but final alignment is directed by the signaling crew member.

Lowering the Lift Adapter and Disengaging the Crane—When properly positioned over the DPC, the signaling crew member signals the crane operator to lower the adapter into place. The crane operator then proceeds to lower the adapter at or below the maximum allowable speed. Once the adapter is in place on the DPC shield plug, the crew member disengages the grapple, and the crane lifts to its maximum height in preparation for the next operation.

Bolting the Lift Adapter to the Shield Plug—A crew member uses the cask preparation platform and common tools to emplace and tighten all the lift adapter bolts (according to training), and then verifies (using a checklist) that all the bolts have been properly installed.

E6.7.1.9 Installation of STC Lid

E6.7.1.9.1 Removal and Storage of the STC Shield Ring

From the DPC cutting platform, the crane operator removes the shield ring using the jib crane and standard rigging, and places it back in the staging area.

The crane operator lowers the jib crane into position over the shield ring and aligns the hook. Once the hook is aligned, the signaling crew member attaches the rigging. Both crew members verify that the load remains level during the lift. If the load is not level on the initial attempt, either crew member can signal the operator to stop and the crane operator then sets the cask down and the crew adjusts the rigging. Once the shield ring is attached properly, the crane operator lifts the shield ring to clear the cask. Once the shield ring is moved clear of the cask, the crane operator lowers the shield ring to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path) and moves the shield ring to the ring stand. The operator bases this on a visual inspection and confirmation by the signaling crew member via hand signals.

E6.7.1.9.2 Placement and Bolting of STC Lid

The crane operator uses the jib crane and lid grapple to place the STC lid on the STC. The crew uses common tools to bolt the lid to the STC (using at least four bolts). This step is verified by quality control. In preparation of this step, the lid grapple must be attached to the crane.

Retrieval of Lid—The crane operator lowers the jib crane with grapple into position over the lid in the staging area, engages the grapple, and lifts the lid to the proper height for movement (roughly 6 in. above the highest obstacle in the movement path). The operator bases this on a visual inspection and confirmation is provided by the signaling crew member via hand signals.

Movement of Lid to the STC—The crane uses the jib crane to position the lid over the STC in the DPC cutting station. The operator follows the indicated safe load path marked on the floor visually, and also receives confirmatory hand signals from the signaling crew member. There is a verification crew member opposite the signaling crew member who can (hand) signal the crane operator to stop at anytime. The crane operator can roughly align the lid over the cask, but final alignment is directed by the signaling crew member.

Lowering Lid and Disengaging the Crane—When properly positioned over the DPC, the signaling crew member signals the crane operator to lower the lid into place. The crane operator then proceeds to lower the lid at or below the maximum allowable speed. Once the lid is in place on the STC, the crew member disengages the grapple and lifts the crane to its maximum height in preparation for the next operation.

Installation of Lid Bolts—Once the lid is in place, the crew member uses the cask preparation platform and common tools to emplace and tighten at least four lid bolts (according to training), and then the supervisor verifies (using a checklist) that the bolts have been properly installed.

E6.7.1.10 Filling the STC with Borated Water

To fill the remainder of the STC, the crew attaches two hoses to the STC (one to the drain port and one to the fill port) via the quick disconnect ports. The other ends of the hoses are in the pool with filters attached. The STC is filled until bubbles are no longer coming out of the return line. The pump is then turned off, the valves are closed, and the hoses are disconnected.

E6.7.2 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 DPC Cutting are summarized in Table E6.7-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

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Table E6.7-1. HFE Group #7 Descriptions and Preliminary Analysis

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
Crane Drops	*Operator Causes Drop of Cask, Canister, or Object during DPC Cutting*: Throughout the DPC cutting operation, several objects are moved over an open cask and the cask itself is moved at least once. These operations utilize the cask handling crane and jib cranes. Each of these lifts can result in a drop which impacts the cask or canister.	15, 17, 18	N/A[a]	In this step, the operator uses the cask handling crane and jib cranes to move the cask and other heavy objects. STCs have one cask lift using the cask handling crane with cask handling yoke; HSTCs have no cask lifts in this HFE group. There are numerous object lifts associated with removing the canister lift fixture (STC/DPC unit) and with DPC cutting: lift of the cask lid (×4), lift of the canister and shield plug lift fixtures, and four movements of the DPC cutting machine (with adapter plate and inner or outer lid). Each of these lifts can potentially result in a drop. These HFEs were not explicitly quantified because the probability of a crane drop due to human failure is incorporated in the historical data used to provide general failure probabilities for drops involving various crane and rigging types. Documentation for this failure can be found in Attachment C.
050-OpCTCollide2-HFI-NOD	*Operator Causes Low-Speed Collision of CTT during Transfer from Unloading Room to Preparation Station (STC/DPC only)*: Once the DPC is in an STC with the lid on, an operator inflates the CTT and moves the cask from the Cask Unloading Room to the Cask Preparation Area. The operator can cause the CTT to collide with the preparation platform during this transfer. The CTT is designed such that it physically cannot over speed; therefore, all CTT collisions are below the designed speed.	14	1E−03	In this step, the CTT moves from the Cask Unloading Room to the preparation station; the doors of the preparation station must be opened to allow the CTT to pass through. There are three observers with clear visibility, the speed of the CTT is low, the CTT is very visible, and there are two guide rails and an end stop to keep the CTT on the safe load path. The CTT could collide into conveyance or facility structures (i.e., preparation station platform or shield door). This could happen if the guide rails were not installed properly. This operation is simple, straightforward, and is expected to occur very regularly (daily), and was assigned the default probability of a "highly unlikely" occurrence (0.001) and not adjusted further. It was considered reasonable and consistent that the preliminary value assigned for this HFE be less likely than a railcar collision because of the guide rail, number of observers, and short travel distance.
050-OpImpact0000-HFI-NOD	*Operator Causes Impact of Cask during Transfer from Cask Unloading Room to Cask Preparation Station (STC/DPC only)*: While moving from the Cask Unloading Room to the cask preparation station, the CTT can impact the crane hook or rigging if it is improperly stowed.	14	N/A	While moving from the Cask Unloading Room to the cask preparation station, the CTT 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 cask preparation platform. It is unlikely, then, that the crane rigging can be improperly stowed such that it impacts the CTT while it is moving out of the Cask Unloading Room to the cask preparation station; it is more likely that rigging could impact the cask while the crane is actually in use. Therefore, any crane interference with the CTT is already covered by 050-OpTCImpact01-HFI-NOD (Operator Causes Cask Impact during DPC cutting) and 050-OpTipover001-HFI-NOD (Operator Causes Cask to Tip Over). This failure was omitted from analysis.
050-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance (STC/DPC only)*: Once the CTM activities are over, an operator opens the shield door, turns on the CTM, lifts the forks, and moves the cask from the Cask Unloading Room to the Cask Preparation Area. There is a shield door between the Cask Preparation Area and the Cask Unloading Room. The operator can impact the cask by inadvertently closing the shield door on the CTT as the CTT passes through the door.	12	1.0	The CTT passes through a shield door as it moves between the cask preparation station and the Cask Unloading Room. During this transfer, the operator can cause the CTT to collide into the shield door or can close the shield door on the CTT. Section E6.0.2.3.3 provides a justification of this preliminary value.
050-OpFLCollide2-HFI-NOD	*Operator Causes Collision of Auxiliary Vehicle with the Cask*: Operator can cause an auxiliary vehicle to collide into a cask while it is stationed at the cutting station. If the collision is due to the auxiliary vehicle speed governor malfunctioning, this would be a high-speed collision.	15	N/A	The operator can cause an auxiliary vehicle (i.e., forklift) to collide with the cask while it is stationed in the DPC cutting station during DPC cutting. This failure was omitted from analysis because the design of the DPC cutting station precludes the cask from being impacted by an auxiliary vehicle.
050-OpTipOver001-HFI-NOD	*Operator Causes Tipover of Cask*: If the operator improperly stows the crane rigging, during DPC cutting or precutting preparation, it can catch the CTT, cask, or canister. If the crane becomes attached to the CTT, cask or canister and the operator continues to move the CTT (i.e., exiting the Cask Preparation Area) or crane, the cask could tip over.	15	1E−04	In this step, there are several crane operations using the cask handling crane and jib cranes. For crane operations there are three observers with clear visibility, the operations are simple, the travel distances are short, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a very regular (daily) basis. There are no interlocks to prevent this error. The contributors to cask tipover include: • Crane hook, grapple, or rigging catches conveyance/cask • Horizontal movement of cask with the hook lowered and attached to the cask • Crane travels in the wrong direction • Cask not lifted high enough to clear the conveyance. The dominant contributor is the crane hook catching the cask. While it may be unlikely (0.01) that a stray hook or grapple might be hanging from the crane, it would still need to catch on the cask securely enough to pull it over (0.1) and then the cask tipping would have to go unnoticed by all three observers. This is done under direct observation, there are not many surfaces which are "catchable," and tipover is a slow process; therefore the value was adjusted by a further 0.1.

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Table E6.7-1. HFE Group #7 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpTCImpact01-HFI-NOD	*Operator Causes an Impact Between Cask and SSC*: While moving the STC with the cask handling crane from the Cask Preparation Area to the DPC cutting station, the crane operator can impact the cask by moving the crane outside the safe load path or by colliding the cask with an SSC in the safe load path. Once the cask is at the cutting station, several objects are moved to and from the cask. Likewise, the crane operator can impact the cask with an object if the crane is moved with the hook too low or otherwise outside of the safe load path.	15	3E−03	In this step an STC is moved from the CTT to the DPC cutting station. There are also several object movements around the cask during DPC cutting. For crane operations in this step there are three observers with clear visibility, the operations are simple, the travel distances are short, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a very regular (daily) basis. There are no interlocks to prevent this error. The dominant contributors to the impact of a cask include: • Crane is moved outside its safe load path (i.e., operators cut corners) • Crane is moved in the wrong direction • Failure to maintain proper vertical and horizontal distance between the cask and SSCs during crane operations. The operator must manually maintain movement within the safe load path. It is not unlikely that the operator would stray slightly from that path, or that an object may be slightly within that path. However, these crane operations are very slow and within clear direct view of three observers. The likelihood of impacting a cask was assessed to be comparable to the crane impact during upending and removal HFE (050-OpTCImpact01-HFI-NOD; Section E6.2, HFE Group #2) and was accordingly assigned the same preliminary value: this failure is "highly unlikely" (one in a thousand or 0.001, which also corresponds to the generic failure rate for a simple operation that is performed daily) but is adjusted because there are several ways for an impact to occur (×3).
050-OpDPCShield2-HFI-NOW	*Operator Causes Loss of Shielding during DPC Cutting*: In this step, the DPC cutting activities are carried out. The crane operator can improperly place the DPC shield ring on the STC during cutting activities, resulting in a direct exposure to the DPC cutting crew.	29	1E−02	In this step, the DPC shield ring is placed over the annulus so the crew can perform DPC cutting activities. During this operation there are three observers plus a supervisor, the crane operations are simple, the ring is attached via sling to the crane, the crane speed is slow, the crew is well trained, and the operators are expected to perform these operations on a weekly basis. There are no interlocks to prevent this error. To add to the complexity of this task, the actual alignment is done via camera; however, if the shield ring is misaligned, it can be seen from the platform. This operation was given the default preliminary value for an event performed on a regular basis (weekly) that is not particularly complex. This is classified as an "unlikely" event and a value of 0.01 applied.
050-OpDPCShield3-HFI-NOW	*Operator Causes Loss of Shielding while Removing DPC Lift Fixture (TC/DPC only)*: In this step, the DPC canister lift fixture is removed from the canister. An operator can fail to properly close and verify the closure of the shield plate. The crew continues with the installation, or can inadvertently open the shield plate while the crew is installing the canister lift fixture.	29	1E−03	In this step, the DPC canister lift fixture is removed from the canister. If an operator fails to properly close the shield plate, then the crew can be directly exposed to the shine from the DPC while removing the canister lift fixture. Likewise, if an operator inadvertently opens the shield plate while the crew is removing the canister lift fixture, then the crew can be exposed. In this case, the crew is on top of the shield plate and would notice if the shield plate moves. The crew is highly trained and, although they only perform DPC preparation activities weekly, they are accustomed to operating the shield plate during preparation of other transportation casks. In addition to the crew members, there is also a radiation protection worker present who is monitoring activities. This error was assessed to be highly unlikely and given a preliminary value of 0.001. This failure is identical to loss of shielding during DPC preparation activities (050-OpDPCShield1-HFI-NOW; HFE Group #5).
050-LidDisplace1-HFI-NOD	*Operator Inadvertently Displaces Lid.*	29	N/A	In this step the lid is unbolted and, for transportation casks/DPCs, other crane operations are performed. Due to design changes to the preparation platform, improperly stowed rigging during this operation would not catch the lid lift fixture. These design changes include raising the platform and adding a shield plate so that the cask is recessed underneath the platform and protected.
050-OpSampleRel2-HFI-NOD	*Operator Improperly Performs Gas Sampling*: Gas sampling may be performed to determine if the fuel has been damaged by the transportation process. If the gas sampling process is incorrectly performed, such that material is released from the sample line, then a radiation release would result if the fuel inside is damaged.	17	5E−03	In this step, the crew samples the cask via a quick-disconnect gas sampling port to ensure that the fuel is intact before removing the canister lid. There is one operator in charge of gas sampling. In order to get a release from the line, the line would have to be inappropriately attached such that the quick disconnect valve is engaged and open. This EOC was assessed to be "highly unlikely" (0.001) because the operation is simple and performed on a daily basis by a highly trained individual. This value was adjusted (×5) to account for the fact that this operation is performed by one crew member, and a failure would be very difficult to notice and correct before material is released. Note: this is the probability of release given damaged fuel; for release of radioactivity to occur, the probability of damaged fuel would have to be assessed and applied.
050-OpDPC-OVP01-HFI-NOW	*Operator Causes DPC Overpressurization*: While cooling the DPC, the operators can cause the DPC to over pressurize by pumping the water too fast. The system is designed to accommodate the hot DPCs (temperatures greater than 350°C); therefore there is not a human-induced overpressurization event if the DPC is not at a low temperature before cooling begins (i.e., due to steam pressure).	17	5E−03	In this step, the crew cools the DPC by running borated water through the canister. While cooling the DPC, the operators can cause the DPC to over pressurize by pumping the water too fast. In order to get the overpressurization, the operator would have to fail to set the water flow rate properly and fail to notice and reduce the flow once the alarms indicated that there was a problem. This EOC was assessed to be "highly unlikely" (0.001) because the operation is simple, performed by a highly trained individual and has associated alarms. This value was adjusted (×5) to account for the fact that this operation is performed by one crew member and is only performed weekly. This was assessed to be comparable to failure of the operator to properly perform gas sampling (050-OpSampleRel2-HFI-NOD), and the preliminary values reflect this.

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Table E6.7-1. HFE Group #7 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Brief Description	ESD	Preliminary Value	Justification
050-OpExpose-Splash	*Operator Exposed Due to Pool Splash*: If the cask is dropped into the pool while the operator is standing too close to the edge of the pool, then the operator can get a direct exposure from the water.	30	1.0	If the cask is dropped into the pool while the operator is standing too close to the edge of the pool, then the operator can get a direct exposure from the water. The probability of an operator being in splash-range of the pool was conservatively assessed to be 1.0.

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

CTM = canister transfer machine; CTT = cask transport trolley; DPC = dual-purpose canister; EOC = error of commission; ESD = event sequence diagram; HFE = human failure event; N/A = not applicable; SSC = structure, system, or component; SSCs = structures, systems, and components; STC = shielded transfer cask; TC = transportation cask.

Source: Original

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E6.7.3 Detailed Analysis

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

Step 5: Identify Potential Vulnerabilities

Prior to defining specific scenarios that can lead to the HFEs of interest (Step 6), information is collected to define the context in which the failures are most likely to occur. In particular, analysts search for potential vulnerabilities in the operators' knowledge and information base for the initiating event or base case scenario(s) under study that might result in HFEs or unsafe actions. This information collection step is discussed in Section E6.7.3.2.

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

An HFE scenario is a specific progression of actions with a specific context that leads to the failure of concern; each HFE is made up of one or more HFE scenarios. In this step, documented in Sections E6.7.3.3 and E6.7.3.4, the analyst identifies deviations from the base case scenario that are likely to result in risk-significant unsafe action(s). These unsafe actions make up an HFE scenario. In serious accidents, these HFE scenarios are usually combinations of various types of unexpected conditions.

Step 7: Quantify Probabilities of HFEs

Detailed HRA quantification methods are selected as appropriate for the characteristics of each HFE and are applied as explained in Section E6.7.3.4. Four quantification methods are utilized in this quantification:

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

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

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

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

Step 8: Incorporate HFEs into the PCSA

After HFEs are identified, defined, and quantified, they must be incorporated into the PCSA. The summary table of HFEs by group that lists the final HEP by basic event name provides the link between the HRA and the rest of the PCSA. This table can be found in Section E6.7.4.

E6.7.3.1 Human Failure Events Requiring Detailed Analysis

The detailed analysis methodology, Sections E3.2.5 through E3.2.9, states that HFEs of concern are identified for detailed quantification through the preliminary analysis (Section E3.2.4). An initial quantification of the WHF PCSA model determined that there were only three HFEs whose preliminary values were too high to demonstrate compliance with the performance objectives stated in 10 CFR 63.111. These HFEs are presented in Table E6.7-2.

Table E6.7-2. Group #7 HFEs Requiring Detailed Analysis

HFE	Description	Preliminary Value
050-OpDPCShield2-HFI-NOW	Operator causes exposure due to failure to install DPC shield ring	1E−02
050-OpDPC-OVP01-HFI-NOW	Operator causes overpressurization of DPC during DPC Cutting	5E−03
050-OpDPCShield3-HFI-NOW	Operator causes loss of shielding while removing DPC lift fixture (STC/DPC only)	1E−03

NOTE: DPC = dual-purpose canister; HFE = human failure event; STC = shielded transfer cask.

Source: Original

E6.7.3.2 Assessment of Potential Vulnerabilities (Step 5)

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

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

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

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

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

The vulnerabilities discussed in this section pertain only to those aspects of the DPC cutting operation that relate to potential human failure scenarios relevant to the three HFEs listed in Table E6.7-2. Other vulnerabilities exist that would be relevant to other potential HFEs that can occur during DPC cutting operations, but these have no bearing on this analysis.

E6.7.3.2.1 Operating Team Characteristics

The operating team consists of the following personnel:

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

Crew Members (two)—Crew members are trained in tasks required for DPC cutting operations. Training consists of observation and "hands-on" instruction. The crew members assist in various tasks of the operation, including bolting and unbolting activities. There is a crew member designated to operate the shield plate on the cask preparation platform, but this crew member is also involved in bolting, unbolting, and other related operations.

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

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

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

Supervisor—The supervisor, or some other personnel with comparable training and certification, is present during DPC cutting activities. This person supervises and checks critical operations, including shield ring installation and DPC filling. No credit for supervisor checks has been given for this HFE group.

E6.7.3.2.2 Operation and Design Characteristics

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

Interlocks/Alarms—An interlock shuts off the DPC cooling pump motor upon overpressurization and an alarm sounds when the pressure gets too high. There are no interlocks or alarms associated with radiation protection that are credited in this task. A radiation protection worker takes a manual reading of radiation levels and prevents operations from proceeding if high radiation levels are detected.

Pressure Relief Capability—There is pressure relief capability associated with the DPC cooling system. This capability is either integral to the quick disconnect valves or a separate pressure relief valve is in series with each quick disconnect valve. These pressure relief valves do not vent directly to atmosphere, but are vented to the HVAC off-gas lines in the case of vapor or to the DPC drain line to filtration prior to water return to the pool in the case of liquid.

E6.7.3.2.3 Operational Conditions

Verbal communication—Verbal communication between crew members and the crane operator is considered to be ineffective. A significant amount of machine noise is present, so hand signals are the only practical means of communication during DPC cutting operations.

E6.7.3.2.4 Formal Rules and Procedures

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

Formal Rule—This operation involves potential radiation exposure, so a formal rule exists that the radiation protection worker must measure the radiation in the area of the DPC where the workers are conducting operations. However, the radiation protection workers do not have to formally sign off on the measurement; they simply need to inform the crane operator and crew that it is safe to continue.

E6.7.3.2.5 Operator Tendencies and Informal Rules

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

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

E6.7.3.2.6 Operator Expectations

Shield ring installation is a simple task ancillary to the main task of DPC cutting. The operator and crew expect that it should go smoothly.

E6.7.3.3 HFE Scenarios and Expected Human Failures (Step 6)

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

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

Table E6.7-3 summarizes all of the HFE scenarios developed for the HFEs in HFE Group #7.

Table E6.7-3. HFE Scenarios and Expected Human Failures for HFE Group #7

HFE	HFE Scenarios
050-OpDPCShield2-HFI-COW *Operator Causes Loss of Shielding During DPC Cutting*	HFE Scenario 1(a): (1) Crane operator fails to install the shield ring; (2) Crew members fail to realize that the shield ring installation has been skipped, and (3) Crew members fail to notice that the shield ring is not in place prior to approaching the DPC. HFE Scenario 1(b): (1) Crane operator installs shield improperly, (2) Radiation protection worker fails to check radiation levels OR radiation protection worker misreads radiation levels OR radiation monitor fails, and (3) Crew member fails to note that the shield ring is out of position before approaching the DPC.
050-OpDPC-OVP01-HFI-NOW *Operator Causes DPC Overpressurization*	HFE Scenario 2(a): (1) Operator pumps borated water at faster than acceptable rate, (2) Operator fails to notice pressure increase or fails to stop operation given the pressure increase; ,and (3)Pressure relief valve fails to operate OR pump motor fails to shut off upon overpressure.
050-OpDPCShield3-HFI-NOW *Operator Causes Loss of Shielding While Removing DPC Lift Fixture*	This HFE is identical to the direct exposure during DPC lift fixture installation (050-OpDPCShield1-HFI-COW; E 6.5, HFE Group #5: DPC Preparation Activities) and the detailed analyses are also identical; therefore, the analysis is not repeated here.

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

Source: Original

Since there are three HFEs identified for detailed analysis in this group, the scenarios are organized under these HFE categories, with the scenarios numbered for the first category as 1(a) and 1(b), and the second category numbered as 2(a).

Each HFE scenario is in turn characterized by several unsafe actions, numbered sequentially as (1), (2), and (3). The Boolean logic of the HFE scenarios is expressed with an implicit AND connecting the subsequent unsafe actions and OR notation wherever two unsafe action paths are possible, as shown in Table E6.7-3.

The HFE scenarios summarized in Table E6.7-3 are discussed and quantified in detail in the following sections.

E6.7.3.4 Quantitative Analysis (Step 7)

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

This section provides a description of the quantitative analysis performed. This quantitative analysis is structured hierarchically by each HFE category (identified by a basic event name), followed by the HFE scenario, and then followed by the unsafe actions under each scenario as documented in Table E6.7-3.

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

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

E6.7.3.4.1 Common Values used in the HFE Detailed Quantification

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

E6.7.3.4.2 Quantification of HFE Scenarios for 050-OpDPCShield2-HFI-NOW: Operator Causes Exposure due to Failure to Install DPC Shield Ring

E6.7.3.4.2.1 HFE Group #7 Scenario 1(a) for 050-OpDPCShield2-HFI-NOW:

1. Crane operator fails to install shield ring.
2. Crew members fail to realize that the shield ring installation has been skipped.
3. Crew members fail to notice that the shield ring is not in place prior to approaching the DPC.

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

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

- CFF E5: Action missed, not performed (omission). The baseline HEP is 0.03
- CPC "Available Time": The general level of time pressure for the overall process of preparing the DPC is very low. There is no particular impetus for getting the task done that would potentially drive the operator to skipping this task. The CPC weighting factor for an execution task with adequate time is 0.5.
- CPC "Adequacy of Training and Preparation": This routine task is well trained and practiced and performed quite frequently. The CPC weighting factor for an execution task with adequate training and high experience is 0.8.

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

Applying these factors yields the following:

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