

BSC

Calculation/Analysis Change Notice

1. QA: QA
2. Page 1 of 24

Complete only applicable items.

3. Document Identifier: 51A-PSA-IH00-00100-000-00A		4. Rev.: 00A	5. CACN: 002
6. Title: Initial Handling Facility Event Sequence Development Analysis			
7. Reason for Change: Change text of fifth bullet on page 12 per Condition Report 11989 Corrective Action 002. Provide for increased clarity and traceability by filling in blank cells in tables in response to Condition Report 12105 Corrective Action 012. Rectify lack of traceability in MLDs for precursor events identified in the HAZOP in response to Condition Report 12121 Corrective Action 006.			
8. Supersedes Change Notice:		<input type="checkbox"/> Yes If, Yes, CACN No.: _____ <input checked="" type="checkbox"/> No	
9. Change Impact:			
Inputs Changed:		Results Impacted:	
<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	
Assumptions Changed:		Design Impacted:	
<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	
10. Description of Change: To resolve CR 11989, Action 002, the fifth bullet on page 12 is replaced by the following: <ul style="list-style-type: none">Intentional malevolent acts, such as sabotage and other security threats, were considered in a separate safeguards and security analysis performed by others. To resolve CR 12105, Action 012, the blank cells in Table 10, with the exceptions summarized in the next paragraph, are filled with em-dashes, indicating that no data belonged in those cells. Also to resolve CR 12105, Action 011, the blank cells in Tables E-2 through E-16, with the exceptions summarized in later paragraphs, are filled with em-dashes, "NCI" (for No Cause Identified), or N/A, indicating that no data belonged in those cells. Each occurrence of N/A in the MLD Index Number column of Table E-9 is replaced by em-dash. To resolve CR 12105, Action 012, HAZOP Table Number E-2 is added for Identifiers IHF-I310, IHF-I311, IHF-I313, and IHF-I314 in Table 10. A footnote is added to explain why no ESD Figure Number is needed for Internal Event Identifier IHF-I317 in Table 10. To resolve CR 12105, Action 012, prevention/mitigation suggestions are entered in the "Potential Prevention/Mitigation Design of Operational Feature" column for Node Item Number 10.2 in Table E-12 and Node Item Number 12.4 in Table E-14. To resolve CR 12105, Action 012, notes explaining why it was not necessary to develop the sequence are added to the Notes column for Node Item Numbers 6.1, 6.2, and 6.3 in Table E-8. Notes explaining that sampling is no longer part of the process were added to the Notes column for Node Item Numbers 7.1, 7.2, and 7.3 in Table E-9. A potential outcome is added to the Consequence column for Node Item Number 12.4 in Table E-14. To resolve CR 12121, Action 006, MLD Index numbers are added for Node Item Number 2.9 in Table E-3, Node Item Number 3.4 in Table E-4, Node Item Number 4.5 in Table E-5, Node Item Numbers 6.6, 6.7, and 6.8 in Table E-8, Node Item Numbers 7.6, 7.7, 7.8, 7.12, 7.19, 7.18, 7.20, and 7.21 in Table E-9, Node Item Numbers 9.12 and 9.17 in Table E-11, Node Item Number 10.2 in Table E-12, and Node Item Numbers 12.1, 12.2, 12.3, 12.5, 12.6, 12.7, and 12.8 in Table E-14. Also to resolve CR 12121, Action 006, the descriptions of event IHF-1105 and IHF-1107 in Figure D-11 are generalized to accommodate additional links with the HAZOP tables. Event IHF-1105 is moved from contributing to "Exposure occurring when canister is raised or lowered by CTM" to "Exposures from canister drop." For consistency with 51A-PSA-IH00-00200-000-00A, "Precursor to drop of or impact to canister during CTM lift" is changed to "This step is no longer applicable" in the Notes column for Node Item Number 7.24 in Table E-9 of 51A-PSA-IH00-00100-000-00A.			

11. REVIEWS AND APPROVAL		
Printed Name	Signature	Date
11a. Originator: Daniel Christman	<i>P. Le [Signature] for Dan Christman</i>	08/26/08
11b. Checker: Dave Bradley	<i>[Signature]</i>	08/26/08
11c. EGS: Michael Frank	<i>[Signature]</i>	8/26/08
11d. DEM: Michael Frank	<i>[Signature]</i>	8/26/08
11e. Design Authority: Barbara Rusinko	<i>[Signature]</i>	8/27/08

Other boundary conditions used in the PCSA include:

- Plant operational state. Initial state of the facility is normal with each system operating within its vendor prescribed operating conditions.
- No other simultaneous initiating events. It is standard practice to not consider the occurrence of other initiating events (human-induced or naturally occurring) during the time span of an event sequence because: (a) the probability of two simultaneous initiating events within the time window is small and, (b) each initiating event will cease operations of the waste handling facility which further reduces the conditional probability of the occurrence of a second initiating event, given that the first has occurred.
- Component failure modes. The failure mode of a structure, system, or component (SSC) corresponds to that required to make the initiating or pivotal event occur.
- Fundamental to the basis for the use of industry-wide reliability parameters within the PCSA, such as failure rates, is the use of SSCs within the GROA that conform to NRC accepted consensus codes and standards, and other regulatory guidance.
- Intentional malevolent acts, such as sabotage and other security threats, were considered in a separate safeguards and security analysis performed by others.

The scope of the present analysis includes operations spanning the receipt of transportation casks on rail or truck conveyances into the Cask Preparation Area of the IHF through the loading of waste packages into the transport and emplacement vehicle (TEV) in the Waste Package Loadout Room of the Initial Handling Facility (IHF). Transport by the TEV from its loading position in the Waste Package Loadout Room to the subsurface is covered in the subsurface operations event sequence development analysis.

This analysis includes: a process flow diagram (PFD), a master logic diagram (MLD), a hazard and operability (HAZOP), event sequence diagrams (ESDs), and event trees. Initiating events considered in this analysis include internal events (i.e., events that are initiated within the IHF) as well as external events (i.e., events that are initiated from outside the IHF). However, event sequences for external events (including seismic events) are not developed in this analysis. External events and any associated event sequences are evaluated and documented separately.

6.1.3 Identification of Initiating Events

The identification of initiating events is completed by constructing the MLD and supplementing it with a HAZOP. The methodologies for the MLD and HAZOP are described in Sections 4.3.1.2 and 4.3.1.3, respectively. The MLD diagram and HAZOP deviations for the IHF are provided in Attachment D and E, respectively. A comprehensive list of initiating events identified by the MLD and HAZOP is provided in Table 9 for external events and Table 10 for internal events.

Table 9. List of External Initiating Event Groups

Identifier	General Event Description
IHF-E201	Exposure due to seismic events
IHF-E202	Non-seismic geologic activity (including landslides, avalanches)
IHF-E203	Volcanic activity
IHF-E204	High winds/tornadoes (including wind effects from hurricanes)
IHF-E205	External floods
IHF-E206	Lightning
IHF-E207	Loss of power events
IHF-E208	Loss of cooling capability event (non-power cause, including biological events)
IHF-E209	Aircraft crash
IHF-E210	Nearby industrial/military facility accidents (including transportation accidents)
IHF-E211	Onsite hazardous materials release
IHF-E212	External fires (including forest fires, grass fires)
IHF-E213	Extraterrestrial activity (including meteorites, falling satellites)

Source: Original

Table 10. List of Internal Initiating Events

Identifier	General Event Description	MLD Figure #	HAZOP Table #	ESD Figure #
IHF-101	RC derailment leads to rollover	D-1	E-2	F-1
IHF-102	RC collision leads to impact	D-1	E-2	F-1
IHF-103	TT failure leads to rollover or load drop (HLW only)	D-1	E-2	F-1
IHF-104	TT collision leads to impact (HLW only)	D-1	E-2	F-1
IHF-I301	Internal flooding caused by pipe failure	D-3	—	—
IHF-I302	Internal flooding caused by actuation of fire protection system	D-3	—	—
IHF-I305	Fire affects WP in WP Loadout Room	D-3	—	F-13
IHF-I306	Fire affects WP in WP Positioning Room	D-3	—	F-13
IHF-I307	Fire affects WP in WP Loading Room	D-3	—	F-13
IHF-I308	Fire affects TC in Cask Unloading Room	D-3	—	F-13
IHF-I309	Fire affects TC on CTT in Cask Preparation Area	D-3	—	F-13
IHF-I310	Fire affects TC on RC in Cask Preparation Area (diesel)	D-3	E-2	F-13

Table 10. List of Internal Initiating Events (Continued)

Identifier	General Event Description	MLD Figure #	HAZOP Table #	ESD Figure #
IHF-I311	Fire affects TC on RC in Cask Preparation Area (no diesel)	D-3	E-2	F-13
IHF-I312	Fire affects canister in WP	D-3	—	F-13
IHF-I313	Fire affects TC (diesel)	D-3	E-2	F-13
IHF-I314	Fire affects TC (no diesel)	D-3	E-2	F-13
IHF-I315	Fire affects canister in CTM	D-3	—	F-13
IHF-I316	Fire affects canister in Canister Transfer Area	D-3	—	F-13
IHF-I317	Excessive temperature (excluding internal fire events) ^a	D-3	—	—
IHF-401	Cask preparation crane drops load onto HLW TC (HLW only)	D-4	E-3	F-2
IHF-402	Unplanned conveyance movement while MAP crane is attached to HLW TC or conveyance fixtures leading to cask impact (HLW only)	D-4	—	F-2
IHF-403	Cask preparation crane or cask handling crane failure causes cask impact (HLW only)	D-4	E-3, E-7	F-2
IHF-404	CTM drops object onto canister before grappling canister (HLW only)	D-4	—	F-7
IHF-405	Impact from MAP operations (HLW only)	D-4	E-3	F-2
IHF-501	Cask handling crane failure causes TC drop	D-5	E-4, E-5	F-1, F-2
IHF-502	Operation of cask handling crane causes unplanned conveyance movement and cask drop	D-5	—	F-1, F-2
IHF-503	Unplanned conveyance movement while crane is attached to TC or conveyance fixtures causes cask drop	D-5	—	F-1, F-2
IHF-504	Cask handling crane drops object onto TC	D-5	E-4	F-1, F-2
IHF-505	Unplanned conveyance movement prior to cask clearing pedestal causing cask drop	D-5	—	F-1, F-2
IHF-506	Cask handling crane drops cask	D-5	E-5, E-6	F-1, F-2
IHF-507	Cask tips and drops after placed onto CTT	D-5	E-7	F-1, F-2
IHF-508	Cask collides with object while being moved by cask handling crane resulting in side impact	D-5	E-6	F-1, F-2
IHF-509	Impact from cask preparation platform operations	D-5	E-4	F-1, F-2
IHF-602	Unplanned movement of CTT during cask lid removal leads to cask impact (naval only)	D-6	—	F-4
IHF-603	Heavy load dropped into the cask and onto the canister (naval only)	D-6	E-9	F-4
IHF-604	Operation of cask preparation crane leads to cask tipover (naval only)	D-6	E-9	F-4
IHF-605	Heavy object dropped onto the cask before removal of the lid (naval only)	D-6	—	F-2
IHF-606	Cask preparation crane causes impact to side of cask (naval only)	D-6	E-9	F-2, F-4
IHF-607	Inadvertent displacement of shield ring causes direct exposure (naval only)	D-6	—	F-12
IHF-701	Operation of cask preparation crane leads to cask tipover (HLW only)	D-7	—	F-3

Table 10. List of Internal Initiating Events (Continued)

Identifier	General Event Description	MLD Figure #	HAZOP Table #	ESD Figure #
IHF-702	Cask preparation crane drops object onto cask (HLW only)	D-7	—	F-3
IHF-703	Cask impact resulting from unplanned movement of CTT during installation of cask lid lift fixture (HLW only)	D-7	—	F-3
IHF-705	Cask preparation crane causes impact to side of cask (HLW only)	D-7	—	F-3
IHF-801	Shield door to Cask Unloading Room, closes against CTT resulting in cask impact	D-8	E-10	F-6
IHF-802	Collision with facility structures or equipment during movement resulting in cask impact	D-8	E-10	F-5, F-6
IHF-803	CTT or cask catches crane hook or rigging during movement resulting in cask impact	D-8	—	F-5
IHF-804	CTM drops object (e.g., lid) into the cask (HLW only)	D-8	E-11	F-7
IHF-805	Lid binds during removal resulting in dropped cask (HLW only)	D-8	E-11	F-7
IHF-806	Cask impact resulting from unplanned movement of CTT during lid removal (HLW only)	D-8	—	F-7
IHF-901	Canister drop within CTM	D-9	—	F-7
IHF-902	Canister collision due to CTM failure leading to an impact	D-9	E-12	F-7
IHF-903	Cask Unloading Room or WP Loading Room shielding loss while the canister is being lifted or lowered	D-9	E-11, E-13	F-12
IHF-1001	Improper configuration of the WP in the WPTT	D-10	E-14, E-15	F-12
IHF-1002	CTM crane drops WP inner lid onto canister during placement	D-10	E-14, E-15	F-7
IHF-1003	RHS drops object on WP	D-10	E-15	F-9
IHF-1004	Welding damages canister	D-10	—	F-9
IHF-1005	WPTT derails leading to canister impact	D-10	E-14, E-16	F-8
IHF-1006	Collision between WPTT and facility, structures, or equipment leading to a WP or canister impact	D-10	E-14, E-16	F-8, F-10
IHF-1007	Premature tilt-down of WPTT	D-10	E-14, E-16	F-8, F-10
IHF-1102	WPTT moves while WP is being loaded leading to an impact	D-11	E-13	F-7
IHF-1103	CTT moves during cask unloading leading to an impact	D-11	E-11	F-7
IHF-1104	Spurious movement of CTM bridge or trolley leading to an impact	D-11	—	F-7
IHF-1105	Canister strikes port edge, CTM slide gate, or wall leading to a canister drop	D-11	E-11, E-13	F-7
IHF-1106	Canister crushed during transfer	D-11	E-11, E-13	F-7
IHF-1107	CTM wire rope cut resulting in dropped canister	D-11	E-11, E-13	F-7
IHF-1108	Canister impact or drop caused by CTM motor failure to stop on demand	D-11	E-11, E-13	F-7
IHF-1109	CTM failure leading to canister impact or drop	D-11	E-11, E-13	F-7
IHF-1110	Canister drop in CTM shield bell (with CTM slide gate closed) due to CTM failure	D-11	E-11, E-13	F-7
IHF-1202	WP handling crane drops an object	D-12	E-16	F-11

Table 10. List of Internal Initiating Events (Continued)

IHF-1203	Crane interference with TEV or WPTT	D-12	E-16	F-11
IHF-1204	Failure of the WPTT	D-12	E-16	F-10, F-11
IHF-1205	Failure of WP transfer carriage	D-12	E-16	F-11, F-12
IHF-1206	TEV collision	D-12	—	F-11
IHF-1207	Untimely opening of shield door or personnel door to WP Loadout Room	D-12	—	F-12

NOTE: CTM = canister transfer machine; CTT = cask transfer trolley; HLW = high level radioactive waste; MLD = master logic diagram; RC = railcar; RHS = remote handling system; TC = transportation cask; TEV = transport and emplacement vehicle; WP = waste package; WPTT = waste package transfer trolley.

^a Shipping casks do not require external cooling.

Source: Original

To facilitate ESD development, a unique identification number has been assigned to each initiating event. The numbers consist of “IHF-” to identify the facility, followed by a three- or four-digit number. The last two digits of the identification numbers uniquely identify events on each page of the MLD. The first one or two digits specify the MLD page number. For example, “IHF-312” means “initiating event 12 on the page 3 of the MLD” and “IHF-1207” means “initiating event 07 on page 12 of the MLD.” A slightly different convention has been used for external events: a prefix “E” has been inserted before the page number. Thus, “IHF-E202” means external initiating event 02 on page 2 of the MLD. For internal initiating events associated with heat or flooding, the prefix “I” has been added to differentiate these from the internal initiating events associated more closely with facility operations. No prefix is used for other internal events.

As noted in Section 1, external event sequences are not developed in this analysis. Their treatment here is limited to identifying initiating events within the MLD. Several categories of external hazard can be identified that encompass the spectrum of potential hazards based on an external event screening as presented in the *Monitored Geologic Repository External Events Hazards Screening Analysis* (Ref. 2.2.5). Regrouping these items, 13 categories of external events are identified as potentially applicable to a repository, as listed in Table 9 and are incorporated into the MLD as shown in Attachment D. Some of these categories can be readily screened from further consideration based on other analyses. Specifically, the two categories are: (1) nearby industrial/military facility accidents (including transportation accidents); and (2) an aircraft crash.

Based on *Industrial/Military Activity-Initiated Accident Screening Analysis* (Ref 2.2.58), no specific industrial or military activity is identified near the repository site that could affect repository operations to induce a release or exposure. Therefore, industrial or military activity is screened from further analysis.

The second category, an aircraft crash, is screened out based on the potential frequency of occurrence during the 50-year emplacement period. An evaluation of the potential for an aircraft crash into repository facilities is presented in *Frequency Analysis of Aircraft Hazards for License Application* (Ref 2.2.21), Section 7. It is noted that Category 2 event sequences are defined in

Table E-2. HAZOP Worksheet for Node 1

Facility/Operation: IHF				Process: Receipt and Transfer into Cask Preparation Area			
Node 1: Receive Railcar or Truck Trailer Carrying TC into Cask Preparation Area (see Attachments B and C for node definitions)				Process/Equipment: SPM, Railcar, Truck Trailer			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
1.1	Speed	(More) SPM moves too fast	Driver drives SPM too fast	Potential loss of control or collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training	Creeping speed	IHF-102
1.2	Speed	(More) SPM moves too fast	Collision	Potential loss of control or collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training	Creeping speed	IHF-102
1.3	Speed	(Less) SPM moves too slow	Mechanical failure of SPM	No safety consequences	—	—	—
1.4	Speed	(No) SPM does not move	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
1.5	Direction	(Reverse) SPM backs up instead of going forward	Collision due to 1 – Human failure 2 – Mechanical failure	Potential loss of control or collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training	Potential loss of HVAC boundary if collision with door	IHF-102
1.6	Direction	(Other Than) Derailment or rollover of carrier	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training	IHF-101 applies to both waste forms. IHF-103 applies only to HLW.	IHF-101 IHF-103
1.7	Direction	(Other Than) Derailment of carrier	Rail distortion due to structural failure	Potential drop of TC leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training 3 – Rail design	—	IHF-101
1.8	Direction	(Other Than) SPM does not follow designated route and goes to wrong location or problem area	Collision due to 1 – Human failure 2 – Mechanical failure	Potential loss of control or collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training	Faulty track or switch indicator, improper directions, or failure to follow directions	IHF-102
1.9	Parking	(Other Than) Improper positioning and constraint of cask conveyance	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training 3 – Brakes, chocks, and rail stops	Collision caused by unconstrained cask conveyance	IHF-102
1.10	Temperature	(More) Exceeds 10 CFR Part 71 temperature design basis	Fire	1 – Potential radioactive release 2 – Potential criticality	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training 3 – Combustible materials control	1 – 10 CFR Part 71 temperature design basis 2 – SPM may contain liquid fuel that could feed a fire in the Cask Preparation Area 3 – SPM may provide other combustible materials 4 – Entrance into facility to be controlled	IHF-I310 IHF-I311 IHF-I313 IHF-I314
1.11	Temperature	(Less) Below 10 CFR Part 71 temperature design basis	Normal condition	No safety consequences	—	—	—
1.12	Shielding	(Less) Displacement of TC shielding	Impact or fire	Direct exposure	1 – TC remains in 10 CFR Part 71 configuration 2 – Procedures and training 3 – Combustible materials control	Includes reduction or complete loss of shielding. IHF-103 and IHF-104 apply only to HLW.	IHF-101 IHF-102 IHF-103 IHF-104

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.
 HVAC = heating, ventilation, and air conditioning; IHF = Initial Handling Facility; SPM = site prime mover; TC = transportation cask.

Source: Original; 10 CFR Part 71 (Ref. 2.3.3).

Table E-3. HAZOP Worksheet for Node 2

Facility/Operation: IHF				Process: Unloading TC from Carrier			
Node 2: Remove Impact Limiters from HLW TC on Carrier (see Attachments B and C for node definitions)				Process/Equipment: Railcar, Truck Trailer, Cask Preparation Crane, Mobile Access Platform			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
2.1	Load	(More) Load lifted too heavy for crane	Failure to remove restraining bolt on impact limiters	Potential drop of TC leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Crane design and below-the-hook devices	Cask preparation crane	IHF-401
2.2	Load	(Less) Load lifted too light	NCI	No safety consequences	—	—	—
2.3	Speed (Crane)	(More) Hook lowered too fast	1 – Human failure 2 – Mechanical failure	Drop of hook leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Crane design	—	IHF-401
2.4	Speed (Crane)	(Less) Hook lowered too slow	NCI	No safety consequences	—	—	—
2.5	Travel (Crane)	(Other Than) Crane movement with hook lowered	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Crane design	—	IHF-403
2.6	Travel (Crane)	(More) Crane moves past desired position for activity	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
2.7	Travel (Crane)	(Less) Crane does not move into desired position for activity	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
2.8	Travel (Crane)	(Reverse) Travels in wrong direction	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Crane design	—	IHF-403
2.9	Motor	(More) Motor temperature too high	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Potential fire scenario	IHF-I309 IHF-I310 IHF-I311 IHF-I312 IHF-I313 IHF-I314 IHF-I315
2.10	Maintenance	(No) Improper maintenance of crane	Human failure	—	Maintenance program	Considered in event sequence development (event tree/FTA/HRA)	—
2.11	Controls (PLC)	(Other Than) Improper signal generated	NCI	—	—	Considered in event sequence development (event tree/FTA/HRA)	—
2.12	Vision/Communication	(Other Than) Unclear communication	Poor operating environment	—	1 – Crane operator training program 2 – Human factor evaluation 3 – Industrial hygiene standards	Considered in HRA	—
2.13	Alignment	(Other Than) Improper alignment	See 2.5 through 2.8 above	—	—	—	—
2.14	Mobile Access Platform Operations	(Other Than) Impact from operational activities	1 – Human failure 2 – Mechanical failure	Potential impact leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Platform and tool design	—	IHF-405

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.

FTA = fault-tree analysis; HLW = high-level radioactive waste; HRA = human-reliability analysis; IHF = Initial Handling Facility; NCI = no cause identified; PLC = programmable logic controller; TC = transportation cask.

Source: Original

Table E-4. HAZOP Worksheet for Node 3

Facility/Operation: IHF				Process: Unloading TC from Carrier			
Node 3: Attach Lift Yoke to TC on Railcar or Truck Trailer (see Attachments B and C for node definitions)				Process/Equipment: Railcar, Truck Trailer, Cask Handling Crane, Lift Yoke, Trunnions (as required)			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
3.1	Speed (Crane)	(More) Yoke lowered too fast	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – Procedures and training 2 – Crane design	TC design may mitigate event, depending on passive equipment failure analysis	IHF-504
3.2	Speed (Crane)	(Less) Yoke lowered too slow	NCI	No safety consequences	—	—	—
3.3	Travel (Crane)	(Other Than) Crane movement with yoke lowered	1 – Human failure 2 – Mechanical failure	Potential collision leading to radioactive release	1 – Procedures and training 2 – Crane design	TC design may mitigate event, depending on passive equipment failure analysis	IHF-501
3.4	Motor	(More) Motor temperature too high	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Potential fire scenario	IHF-I309 IHF-I310 IHF-I311 IHF-I312 IHF-I313 IHF-I314 IHF-I315
3.5	Maintenance	(No) Improper maintenance of crane	Human failure	—	Maintenance program	Considered in event sequence development (event tree/FTA/HRA)	—
3.6	Controls (PLC)	(Other Than) Improper signal generated	NCI	—	—	Considered in event sequence development (event tree/FTA/HRA)	—
3.7	Vision/Communication	(Other Than) Unclear communication	Poor operating environment	—	1 – Crane operator training program 2 – Human factor evaluation 3 – Industrial hygiene standards	Considered in HRA	—
3.8	Mobile Access Platform Operations	(Other Than) Impact from operational activities	1 – Human failure 2 – Mechanical failure	Potential impact leading to radioactive release	1 – TC design 2 – Procedures and training 3 – Platform and tool design	—	IHF-509
3.9	Engagement (Yoke)	(More) Yoke arm over-travel	1 – Human failure 2 – Mechanical failure	Potential drop of TC leading to radioactive release	1 – Positioning interlocks 2 – Yoke adjustment motor design 3 – Pin alignment 4 – Procedures and training	—	IHF-501
3.10	Engagement (Yoke)	(Less) Yoke arm under-travel	1 – Human failure 2 – Mechanical failure	Potential drop of TC leading to radioactive release	1 – Positioning interlocks 2 – Yoke adjustment motor design 3 – Pin alignment 4 – Procedures and training	Potential partial yoke engagement	IHF-501
3.11	Engagement (Yoke)	(No) Failed to engage	NCI	No safety consequences	—	—	—
3.12	Yoke	(Other Than) Trunnion installed incorrectly	1 – Human failure 2 – Mechanical failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Trunnion design	As required for certain casks	IHF-501

NOTE: Guidewords "Reverse," "As Well As," and "Part Of" were not used in this node.

FTA = fault-tree analysis; HRA = human-reliability analysis; IHF = Initial Handling Facility; NCI = no cause identified; PLC = programmable logic controller; TC = transportation cask.

Source: Original

Table E-5. HAZOP Worksheet for Node 4

Facility/Operation: IHF				Process: Unloading TC from Carrier			
Node 4: Upright TC on Railcar (see Attachments B and C for node definitions)				Process/Equipment: Railcar, Truck Trailer, Cask Handling Crane			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
4.1	Load	(More) Load lifted too heavy for crane	Failure to remove tie-downs	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Crane design	1 – Cask handling crane main hook 2 – TC design may mitigate event, depending on passive equipment failure analysis	IHF-501
4.2	Load	(Less) Load lifted too light	NCI	No safety consequences	—	—	—
4.3	Speed (Crane and Hook)	(More or Less) Hook and crane speed not matched during lifting motion	1 – Human failure 2 – Mechanical failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Crane design and below-the-hook design	TC design may mitigate event, depending on passive equipment failure analysis	IHF-501
4.4	Travel (Crane)	(Reverse) Travels in wrong direction	1 – Human failure 2 – Mechanical failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Crane design and below-the-hook design	1 – TC design may mitigate event, depending on passive equipment failure analysis 2 – Crane feature to prevent rapid rundown needs to be subjected to FTA	IHF-501
4.5	Motor	(More) Motor temperature too high	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Potential fire scenario	IHF-1309 IHF-1310 IHF-1311 IHF-1312 IHF-1313 IHF-1314 IHF-1315
4.6	Motor Motive Force	(Less or No) Loss of motive force allows rapid rundown	1 – Human failure 2 – Mechanical malfunction	Potential drop of TC leading to radioactive release	—	1 – TC design may mitigate event, depending on passive equipment failure analysis 2 – Crane feature to prevent rapid rundown needs to be subjected to FTA	IHF-501
4.7	Maintenance	(No) Improper maintenance of crane	Human failure	Potential drop of TC leading to radioactive release	Maintenance program	Considered in event sequence development (event tree/FTA/HRA)	IHF-501
4.8	Controls (PLC)	(Other Than) Improper signal generated	NCI	—	—	Considered in event sequence development (event tree/FTA/HRA)	—
4.9	Vision/Communication	(Other Than) Unclear communication	Poor operating environment	—	1 – Crane operator training program 2 – Human factor evaluation 3 – Industrial hygiene standards	Considered in HRA	—
4.10	Alignment	(Other Than) Improper alignment	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
4.11	Pivot Point	(Other Than) Pivot point constraint fails	Cover brackets fail or are removed out of sequence	Potential radioactive release resulting from slap-down	1 – Transportation skid pedestal design 2 – Procedures and training	—	IHF-506

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.

FTA = fault-tree analysis; HRA = human-reliability analysis; IHF = Initial Handling Facility; NCI = no cause identified; PLC = programmable logic controller; TC = transportation cask.

Source: Original

Table E-6. HAZOP Worksheet for Node 5

Facility/Operation: IHF				Process: Unloading TC from Carrier			
Node 5: Transfer TC from Railcar or Truck Trailer to CTT (see Attachments B and C for node definitions)				Process/Equipment: Railcar, Cask Handling Crane, CTT			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
5.1	Lift	(More) Attempting to lift cask too high (i.e., two-blocking)	1 – Human failure 2 – Mechanical malfunction	Potential drop of TC leading to radioactive release	1 – Crane design 2 – Procedures and training	1 – TC design may mitigate event, depending on passive equipment failure analysis 2 – 20-ft or greater drop considered	IHF-506
5.2	Lift	(Less) Not lifted high enough to clear other structures or equipment	1 – Human failure 2 – Mechanical malfunction	Potential drop of TC leading to radioactive release	Procedures and training	—	IHF-506 IHF-508
5.3	Lift	(No) Not lifted	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
5.4	Lift	(Reverse) Rapid rundown	1 – Human failure 2 – Mechanical malfunction	Potential drop of TC leading to radioactive release	1 – Crane design 2 – Procedures and training	TC design may mitigate event, depending on passive equipment failure analysis	IHF-506
5.5	Speed (Crane)	(More) Crane moves faster than allowed by procedures	1 – Human failure 2 – Mechanical failure	Potential collision of TC leading to radioactive release	1 – Crane design 2 – Procedures and training	TC design may mitigate event, depending on passive equipment failure analysis	IHF-508
5.6	Speed (Crane)	(Less) Crane moves too slow	1 – Human failure 2 – Mechanical failure	—	Procedures and training	Prolonged exposure time for sequence initiation	—
5.7	Speed (Crane)	(Other Than) Abrupt stop	1 – Human failure 2 – Mechanical failure	Potential TC impact leading to radioactive release	1 – Crane design 2 – Procedures and training	TC design may mitigate event, depending on passive equipment failure analysis	IHF-508
5.8	Alignment (CTT)	(No) Improper alignment	Human failure	No safety consequences	—	—	—

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.
CTT = cask transfer trolley; IHF = Initial Handling Facility; TC = transportation cask.

Source: Original

Table E-7. HAZOP Worksheet for Step-By-Step Evaluation of Nodes 1 Through 5

Facility/Operation: IHF				Process: Step-By-Step Evaluation of TC Receipt			
Nodes 1 Through 5: Receive TC on Railcar and Transfer to CTT				Process/Equipment: Various As Needed			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
S.1	N/A	Wrong cask pedestal selected	Human failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Pedestal design	1 – Human factors 2 – Scheduling by campaigns may minimize occurrence	IHF-507
S.2	N/A	Cask handling crane used to remove impact limiters instead of cask preparation crane	Human failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Hook design	Applies to HLW only	IHF-403
S.3	N/A	Yoke selection not consistent with canister	Human failure	No safety consequences	—	Prevented by design of lifting devices, which would preclude connection to wrong type of cask	—

NOTE: No Guidewords were used in this node.
CTT = cask transfer trolley; IHF = Initial Handling Facility; TC = transportation cask.

Source: Original

Table E-8. HAZOP Worksheet for Node 6

Facility/Operation: IHF				Process: TC Preparation			
Node 6: Preparation Operations for HLW Casks (see Attachments B and C for node definitions)				Process/Equipment: Preparation Station, Common Tools			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
6.1	Sample Line Hookup	(Other Than) Improper hookup	Human failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Connection design	Sealed canisters preclude significant radioactive release	—
6.2	Sample Line Hookup	(Other Than) Line breaks	1 – Human failure 2 – Equipment failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Sample system design	Sealed canisters preclude significant radioactive release	—
6.3	Taking Sample	(Other Than) Incorrect or inadequate sample or false negative	1 – Human failure 2 – Equipment failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Sample system design	Sealed canisters preclude significant radioactive release	—
6.4	Jib Crane Load	(More) Too much load for crane	1 – Human failure 2 – Equipment failure	No safety consequences	—	Possible mitigation of event by TC, depending on passive equipment failure analysis	—
6.5	Jib Crane Load	(Less) Too light	NCI	No safety consequences	—	—	—
6.6	Loosen/Remove Bolts	(Other Than) Failure to remove	Human failure	No safety consequences	—	Potential precursor ^a to overloading CTM	IHF-805
6.7	Loosen/Remove Bolts	(Reverse) Tightens bolts instead of loosening	1 – Human failure 2 – Equipment failure	No safety consequences	—	Potential precursor ^a to overloading CTM	IHF-805
6.8	Attach TC Lid Lift Fixture	(Other Than) Improper attachment	1 – Human failure 2 – Equipment failure	No safety consequences	1 – Procedures and training 2 – Potentially precluded by design	Precursor ^a to drop of lid back onto canister	IHF-805

NOTE: Guidewords "No," "As Well As," and "Part Of" were not used in this node.

CTM = canister transfer machine; DOE = U.S. Department of Energy; HLW = high-level radioactive waste; IHF = Initial Handling Facility; NCI = no cause identified; TC = transportation cask.

^aEvents that have no direct safety consequences but may be precursors to events that occur in other nodes are noted as "No safety consequences."

Source: Original

Table E-9. HAZOP Worksheet for Node 7

Facility/Operation: IHF				Process: TC Preparation			
Node 7: Preparation Operations for Naval Casks (see Attachments B and C for node definitions)				Process/Equipment: Preparation Station, Cask Shield Ring, Cask Preparation Crane			
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
7.1	Sample Line Hookup	(Other Than) Improper hookup	Human failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Connection design	Sampling no longer part of the process	—
7.2	Sample Line Hookup	(Other Than) Line breaks	1 – Human failure 2 – Equipment failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Sample system design	Sampling no longer part of the process	—
7.3	Taking Sample	(Other Than) Incorrect or inadequate sample or false negative	1 – Human failure 2 – Equipment failure	Potential release of materials in cask canister annulus to environment	1 – Procedures and training 2 – Sample system design	Sampling no longer part of the process	—
7.4	Jib Crane Load	(More) Too much load for crane	NCI	No safety consequences	—	—	—
7.5	Jib Crane Load	(Less) Too light	NCI	No safety consequences	—	—	—
7.6	Loosen/Remove Lid Bolts	(Other Than) Failure to remove	Human failure	No safety consequences	—	1 – Sequence of bolt removal and installation of lift fixture may impact human failure probability associated with failure to remove bolts 2 – Precursor ^a to cask drop if remaining bolts overloaded	IHF-604
7.7	Loosen/Remove Bolts	(Reverse) Tightens bolts instead of loosening	1 – Human failure 2 – Equipment failure	No safety consequences	—	Potential precursor ^a to cask drop if remaining bolts overloaded	IHF-604
7.8	Attach TC Lid Lift Fixture	(Other Than) Improper attachment	1 – Human failure 2 – Equipment failure	No safety consequences	1 – Procedures and training 2 – Potentially precluded by design	Potential precursor ^a to cask lid drop	IHF-603
7.9	Remove TC Lid	(More) Attempting to lift more than the lid alone	Human failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Crane design features	Model crane overload protection features and failure modes	IHF-604
7.10	Remove TC Lid	(More) Attempting to lift lid too high (i.e., two-blocking)	Human failure	Potential impact to TC leading to radioactive release	1 – Procedures and training 2 – Crane design features	—	IHF-603
7.11	Remove TC Lid	(Less) Not lifting lid high enough to clear cask	Human failure	Potential drop of TC leading to radioactive release	Procedures and training	—	IHF-606
7.12	Remove TC Lid	(Other Than) Lift with fixture improperly attached (see 7.8 above)	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	—	IHF-603
7.13	Remove Closure Shear Ring and Shear Ring Backing Ring	(See 7.9 through 7.12 above)	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	—	IHF-603
7.14	Install Shield Ring	(More) Lift too high	1 – Human failure 2 – Equipment failure	Potential impact to TC leading to radioactive release	Procedures and training	Operations have changed since the HAZOP evaluation was performed. The naval cask shield ring is left in place. This step is no longer applicable.	—
7.15	Install Shield Ring	(Less) Lift not high enough to clear cask	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	This step is no longer applicable.	—
7.16	Install Shield Ring	(No) No installation	Human failure	Direct exposure	Procedures and training	This step is no longer applicable.	—

Table E-9. HAZOP Worksheet for Node 7
(Continued)

Facility/Operation: IHF					Process: TC Preparation		
Node 7: Preparation Operations for Naval Casks (see Attachments B and C for node definitions)					Process/Equipment: Preparation Station, Cask Shield Ring, Cask Preparation Crane		
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
7.17	Install Shield Ring	(Other Than) Improperly installed	Human failure	Direct exposure	Procedures and training	Operations have changed since the HAZOP evaluation was performed. The naval cask shield ring is left in place. This step is no longer applicable.	—
7.18	Install Canister Lift Fixture	(More) Lift too high	1 – Human failure 2 – Equipment failure	Potential impact to TC leading to radioactive release	Procedures and training	—	IHF-603
7.19	Install Canister Lift Fixture	(Less) Lift not high enough to clear cask	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	—	IHF-606
7.20	Install Canister Lift Fixture	(Other Than) Improperly attached to crane for movement to installation position	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	—	IHF-603
7.21	Install Canister Lift Fixture	(Other Than) Improperly installed	Human failure	No safety consequences	Procedures and training	Precursor ^a to drop of canister during lift	IHF-1107
7.22	Remove and Store Shield Ring	(More) Lift too high	1 – Human failure 2 – Equipment failure	Potential impact to TC leading to radioactive release	Procedures and training	This step is no longer applicable.	—
7.23	Remove and Store Shield Ring	(Less) Lift not high enough to clear cask	Human failure	Potential impact to TC leading to radioactive release	Procedures and training	This step is no longer applicable.	—
7.24	Remove and Store Shield Ring	(No) No removal	Human failure	No safety consequences	Procedures and training	This step is no longer applicable.	—

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.

CTM = canister transfer machine; IHF = Initial Handling Facility; NCI = no cause identified; TC = transportation cask.

^aEvents that have no direct safety consequences but may be precursors to events that occur in other nodes are noted as "No safety consequences."

Source: Original

Table E-10. HAZOP Worksheet for Node 8

Facility/Operation: IHF					Process: TC Preparation		
Node 8: Move Loaded CTT to Cask Unloading Room (see Attachments B and C for node definitions)					Process/Equipment: TC Trolley		
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
8.1	CTT Lift	(More) Too much lift	No cause identified	—	—	—	—
8.2	CTT Lift	(Less) Not enough lift	1 – Lack of air pressure 2 – Cone malfunction	No safety consequences	—	—	—
8.3	CTT Lift	(Other Than) Uneven lift	Cone malfunction	No safety consequences	—	Unable to lift more than 5/16-inch over longest dimension	—
8.4	CTT Lift	(Other Than) Drops	Loss of air	No safety consequences	—	—	—
8.5	CTT Movement	(More) Moves too far	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – CTT design 3 – TC design	Shield door open, leading to collision with facility structure	IHF-802
8.6	CTT Movement	(More) Moves too far	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – CTT design 3 – TC design	Shield door closed, leading to collision with shield door	IHF-802
8.7	CTT Movement	(Less) Does not move enough	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
8.8	CTT Movement	(Reverse) Moves in opposite (wrong) direction	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – CTT design 3 – TC design	—	IHF-802
8.9	CTT Movement	(Other Than) Sideways movement	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – CTT design 3 – TC design	—	IHF-802
8.10	Shield Door Movement	(Other Than) Spurious closure of shield door	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – Design of shield-door controls 3 – TC design	—	IHF-801
8.11	Preparation Platform Position	(Other Than) Out of position leading to platform collision with CTT frame	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – CTT design 3 – TC design	—	IHF-802

NOTE: Guidewords "No," "As Well As," and "Part Of" were not used in this node.
CTT = cask transfer trolley; IHF = Initial Handling Facility; TC = transportation cask.

Source: OriginalTable

Table E-11. HAZOP Worksheet for Node 9

Facility/Operation: IHF					Process: CTM Operation		
Node 9: Lift Canister from TC into CTM (see Attachments B and C for node definitions)					Process/Equipment: CTM		
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
9.1	Shield Door Movement	(Other Than) Failure to close shield door	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister removal	IHF-903
9.2	Shield Door Movement	(Other Than) Spurious opening of shield door	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister removal	IHF-903
9.3	Shield Door Movement	(Other Than) Failure to evacuate personnel prior to door closure	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister removal	IHF-903
9.4	Port Slide Gate	(Other Than) Failure to open slide gate	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
9.5	Port Slide Gate	(Other Than) Failure to close slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when CTM moved	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-903
9.6	Port Slide Gate	(Other Than) Untimely opening of port slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when CTM moved	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-903
9.7	Port Slide Gate	(Other Than) Closure while lifting canister	1 – Human failure 2 – Mechanical malfunction	Potential release	1 – Procedures and training 2 – Design of slide-gate controls	Examine rope and canister closures	IHF-1106
9.8	CTM Slide Gate	(Other Than) Failure to open slide gate	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
9.9	CTM Slide Gate	(Other Than) Failure to close slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when skirt lifted	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-903
9.10	CTM Slide Gate	(Other Than) Untimely opening of CTM slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when skirt lifted	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-903
9.11	CTM Slide Gate	(Other Than) Closure while lifting canister	1 – Human failure 2 – Mechanical malfunction	Potential release	1 – Procedures and training 2 – Design of slide-gate controls	Examine rope and canister closures	IHF-1106
9.12	Lid Grapple Engagement	(Other Than) Improper attachment	1 – Human failure 2 – Equipment failure	No safety consequences	1 – Procedures and training 2 – Potentially precluded by design	Potential precursor ^a to cask lid drop	IHF-603
9.13	Remove HLW TC Lid	(More) Attempting to lift lid when bolts have not been removed (see Node 6, Items 6.6 and 6.7)	Human failure	Potential drop of TC leading to radioactive release	1 – Procedures and training 2 – Crane design features	Model crane overload protection features and failure modes	IHF-805
9.14	Remove HLW TC Lid	(More) Attempting to lift lid too high (i.e., two-blocking)	Human failure	Potential impact to canister leading to radioactive release	1 – Procedures and training 2 – Crane design features	Does not apply to naval canisters	IHF-804
9.15	Remove HLW TC Lid	(Less) Not lifting lid high enough to clear cask	Human failure	Potential impact to canister leading to radioactive release	Procedures and training	Does not apply to naval canisters	IHF-804
9.16	Remove HLW TC Lid	(Other Than) Lift with grapple improperly attached (see 9.12 above)	Human failure	Potential impact to canister leading to radioactive release	Procedures and training	Does not apply to naval canisters	IHF-804
9.17	Canister Grapple Engagement	(Other Than) Improper attachment	1 – Human failure 2 – Equipment failure	No safety consequences	1 – Procedures and training 2 – Potentially precluded by design	Potential precursor ^a to canister drop	IHF-1107

Table E-11. HAZOP Worksheet for Node 9
(Continued)

Facility/Operation: IHF				Process: CTM Operation			
Node 9: Lift Canister from TC into CTM (see Attachments B and C for node definitions)				Process/Equipment: CTM			
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
9.18	Lift	(More) Attempting to lift more than a canister (i.e., load hang-up)	Human failure	Potential drop of canister leading to radioactive release	1 – Procedures and training 2 – CTM design features	Model CTM overload protection features and failure modes	IHF-1105
9.19	Lift	(More) Attempting to lift canister too high (i.e., two-blocking)	Human failure	1 – Potential drop of canister leading to radioactive release 2 – Direct exposure if lifted above top of shield bell	1 – Procedures and training 2 – CTM design features	—	IHF-1109
9.20	Lift Canister	(Less) Not lifting canister high enough to clear floor	Human failure	Potential shear of canister leading to radioactive release	Procedures and training	—	IHF-1109
9.21	Lift Canister	(Other Than) Movement of CTT during lift of canister	Human failure	Potential shear of canister leading to radioactive release	1 – Procedures and training 2 – CTT design features	—	IHF-1103
9.22	Lift Canister	(Other Than) Miscellaneous mechanical failures	Mechanical malfunction	Potential drop of canister leading to radioactive release	CTM design features	Maintenance program	IHF-1107 IHF-1108 IHF-1109 IHF-1110
9.23	Lift Canister	(Other Than) Lift with grapple improperly attached (see 9.17 above)	1 – Human failure 2 – Mechanical malfunction	Potential drop of canister leading to radioactive release	Procedures and training	—	IHF-1109

NOTE: Guidewords "No," "Reverse," "As Well As," and "Part Of" were not used in this node.

CTM = canister transfer machine; CTT = cask transfer trolley; HLW = high-level radioactive waste; IHF = Initial Handling Facility; TC = transportation cask.

Source: Original

Table E-12. HAZOP Worksheet for Node 10

Facility/Operation: IHF					Process: CTM Operation		
Node 10: Move CTM from Cask Port to WP Port (see Attachments B and C for node definitions)					Process/Equipment: CTM		
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
10.1	Speed (CTM)	(More) CTM moves faster than allowed by procedures	1 – Human failure 2 – Mechanical failure	Potential collision with canister leading to radioactive release	1 – CTM design 2 – Procedures and training	—	IHF-902
10.2	Speed (CTM)	(No) CTM stuck in middle of room during move	1 – Human failure 2 – Mechanical failure	Potential radioactive release due to heat-up, etc.	1 – Procedures and training 2 – Design features	—	IHF-1307
10.3	Speed (CTM)	(Less) CTM moves too slow	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
10.4	Speed (CTM)	(Other Than) Abrupt stop	1 – Human failure 2 – Mechanical failure	Potential collision with canister leading to radioactive release	1 – CTM design 2 – Procedures and training	—	IHF-902
10.5	Direction (CTM)	(More) CTM moves too far	1 – Human failure 2 – Mechanical failure	Potential collision with canister leading to radioactive release	1 – CTM design 2 – Procedures and training	—	IHF-902
10.6	Direction (CTM)	(Less) CTM does not move enough	1 – Human failure 2 – Mechanical failure	No safety consequences	—	—	—
10.7	Direction (CTM)	(Other Than) Moves in wrong direction	1 – Human failure 2 – Mechanical failure	Potential collision with canister leading to radioactive release	1 – CTM design 2 – Procedures and training	—	IHF-902
10.8	Miscellaneous (CTM)	(Other Than) Moves over lid not properly stored	Human failure	Potential collision with canister leading to radioactive release	1 – Facility design 2 – Procedures and training	—	IHF-902

NOTE: Guidewords "Reverse," "As Well As," and "Part Of" were not used in this node.
CTM = canister transfer machine; IHF = Initial Handling Facility; WP = waste package.

Source: Original

Table E-13. HAZOP Worksheet for Node 11

Facility/Operation: IHF					Process: CTM Operation		
Node 11: Lower Canister from CTM into WP (see Attachments B and C for node definitions)					Process/Equipment: CTM, WP		
Guidewords: No, More, Less, Reverse, Other Than, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
11.1	Shield Door Movement	(Other Than) Failure to close shield door	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister lowering	IHF-903
11.2	Shield Door Movement	(Other Than) Spurious opening of shield door	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister lowering	IHF-903
11.3	Shield Door Movement	(Other Than) Failure to evacuate personnel prior to door closure	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – Design of shield-door controls	Must be concurrent with canister lowering	IHF-903
11.4	Port Slide Gate	(Other Than) Failure to open slide gate	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
11.5	Port Slide Gate	(Other Than) Failure to close slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when CTM moved	1 – Procedures and training 2 – Design of slide-gate controls	After canister lowered into WP	IHF-903
11.6	Port Slide Gate	(Other Than) Inadvertent opening of port slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when CTM moved	1 – Procedures and training 2 – Design of slide-gate controls	After canister lowered into WP	IHF-903
11.7	Port Slide Gate	(Other Than) Closure while lowering canister	1 – Human failure 2 – Mechanical malfunction	Potential release	1 – Procedures and training 2 – Design of slide-gate controls	Examine rope and canister closures	IHF-1106
11.8	CTM Slide Gate	(Other Than) Failure to open slide gate	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
11.9	CTM Slide Gate	(Other Than) Failure to close slide gate	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
11.10	CTM Slide Gate	(Other Than) Opening of CTM slide gate	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure to personnel on second floor when skirt lifted	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-903
11.11	CTM Slide Gate	(Other Than) Closure while lowering canister	1 – Human failure 2 – Mechanical malfunction	Potential release	1 – Procedures and training 2 – Design of slide-gate controls	—	IHF-1106
11.12	Lowering of Canister	(Less) Not lowering canister enough to clear bottom of second floor	Human failure	Potential shear of canister leading to radioactive release	Procedures and training	—	IHF-1109
11.13	Lowering of Canister	(Other Than) Movement of WPTT during lowering of canister	Human failure	Potential shear of canister leading to radioactive release	1 – Procedures and training 2 – WPTT design features	Includes inadvertent movement of WPTT tilting mechanism	IHF-1102
11.14	Lowering of Canister	(Other Than) Miscellaneous mechanical failures	Mechanical malfunction	Potential drop of canister leading to radioactive release	CTM design features	Maintenance program	IHF-1107 IHF-1108 IHF-1109 IHF-1110
11.15	Lowering of Canister	(Other Than) Lowering canister without WP below	1 – Human failure 2 – Mechanical malfunction	Potential direct exposure	Procedures and training	—	IHF-903
11.16	Lowering of Canister	(Other Than) Misalignment of CTM and port	1 – Human failure 2 – Mechanical malfunction	Potential drop of or impact to canister leading to radioactive release	Procedures and training	Potential of catching ledge and dropping into hole	IHF-1105

NOTE: Guidewords "No," "More," "Reverse," "As Well As," and "Part Of" were not used in this node.

CTM = canister transfer machine; CTT = cask transfer trolley; IHF = Initial Handling Facility; TC = transportation cask; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

Table E-14. HAZOP Worksheet for Node 12

Facility/Operation: IHF					Process: WP Operation		
Node 12: Install WP Inner Lid and Move WP to WP Positioning Room (see Attachments B and C for node definitions)					Process/Equipment: CTM, WP, WPTT		
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
12.1	WPTT Preparation	(Other Than) Improper positioning of empty WP in WPTT	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.2	WPTT Preparation	(Other Than) Pedestal not loaded or improper pedestal loaded	Human failure	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.3	WPTT Preparation	(Other Than) Improper alignment of WP to vertical axis when bringing upright	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.4	WPTT Preparation	(Other Than) WP shield ring not installed	Human failure	Potential direct exposure	1 – Procedures and training 2 – Design features	Could cause overexposure of personnel in IHF control room and subject welding equipment to exposure greater than design	IHF-1001
12.5	WPTT Preparation	(Other Than) Wrong WP used for waste form to be loaded	Human failure	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.6	WPTT Movement with Empty WP	(Other Than) Impact or derailment	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.7	WPTT Movement with Empty WP	(Other Than) Misalignment of WP and port	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Precursor ^a to WP loading mishaps	IHF-1105
12.8	Lid Grapple Engagement	(Other Than) Improper attachment	1 – Human failure 2 – Equipment failure	No safety consequences	—	Potential precursor ^a to cask lid drop (WP requires multiple lids)	IHF-1102 IHF-1103
12.9	Install Lid	(Other Than) Install wrong lid or no lid	Human failure	Potential direct exposure	Procedures and training	—	IHF-1001
12.10	Install Lid	(Reverse) Attempting to lift lid too high (i.e., two-blocking)	Human failure	Potential impact to canister leading to radioactive release	1 – Procedures and training 2 – Crane design features	—	IHF-1002
12.11	Install Lid	(Other Than) Lift with grapple improperly attached (see 12.8 above)	Human failure	Potential impact to canister leading to radioactive release	Procedures and training	—	IHF-1002
12.12	WPTT Movement with Loaded WP	(Other Than) Impact or derailment	1 – Human failure 2 – Mechanical malfunction	Potential drop of or impact to WP leading to radioactive release	1 – Procedures and training 2 – Maintenance	Impacts include premature tilting	IHF-1005 IHF-1006 IHF-1007
12.13	Shield Door Movement	(Other Than) Failure to open shield door	1 – Human failure 2 – Mechanical malfunction	Potential collision with WP leading to radioactive release	1 – Procedures and training 2 – Design of shield-door controls	—	IHF-1006
12.14	Shield Door Movement	(Other Than) Closure on WPTT during transit	1 – Human failure 2 – Mechanical malfunction	Potential collision with WP leading to radioactive release	1 – Procedures and training 2 – Design of shield-door controls	—	IHF-1006

NOTE: Guidewords "No," "More," "Less," "As Well As," and "Part Of" were not used in this node.

CTM = canister transfer machine; IHF = Initial Handling Facility; WP = waste package; WPTT = waste package transfer trolley.

^aEvents that have no direct safety consequences but may be precursors to events that occur in other nodes are noted as "No safety consequences."

Source: Original

Table E-15. HAZOP Worksheet for Node 13

Facility/Operation: IHF					Process: WP Operation		
Node 13: Close WP (see Attachments B and C for node definitions)					Process/Equipment: Closure Equipment, WP, WPTT, Inner and Outer Lids		
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of					Consequence Categories: Radioactive Release, Lack of Shielding, Criticality		
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
13.1	WPTT Alignment	(Other Than) Greater than 1-inch deviation from expected position	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	Positioning monitored by camera	—
13.2	Placement of Inner Lid	N/A	NCI	—	—	Inner lid will be placed by CTM for all waste forms	—
13.3	Welding Process Temperature	(More) Greater than expected temperature	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.4	Welding Process Temperature	(Less) Less than expected temperature	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.5	Welding Process Material	(Other Than) Wrong welding material	Human failure	No safety consequences	—	—	—
13.6	Welding Process Material	(More) More than expected amount	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.7	Welding Process Material	(Less) Less than expected amount	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.8	Welding Process Inerting Blanket	(No or Less) Loss of inerting blanket	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.9	Welding Process Inerting Blanket	(Other Than) Flammable gas substituted for inerting gas	Human failure	No safety consequences	—	—	—
13.10	Weld Cooling	(More) Too much cooling	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.11	Weld Cooling	(Less) Localized temperature exceeds limits	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
13.12	Install Lid	(Other Than) Install wrong lid or no lid	Human failure	Potential direct exposure	Procedures and training	—	IHF-1001
13.13	Install Lid	(Reverse) Attempting to lift lid too high (i.e., two-blocking)	Human failure	Potential drop of lid onto WP	1 – Procedures and training 2 – RHS design features	—	IHF-1002
13.14	Install Lid	(Other Than) Lift with grapple improperly attached	Human failure	Potential impact to WP leading to radioactive release	Procedures and training	—	IHF-1003

NOTE: Guidewords "As Well As" and "Part Of" were not used in this node.
IHF = Initial Handling Facility; RHS = remote handling system; WP = waste package; WPTT = waste package transfer trolley.

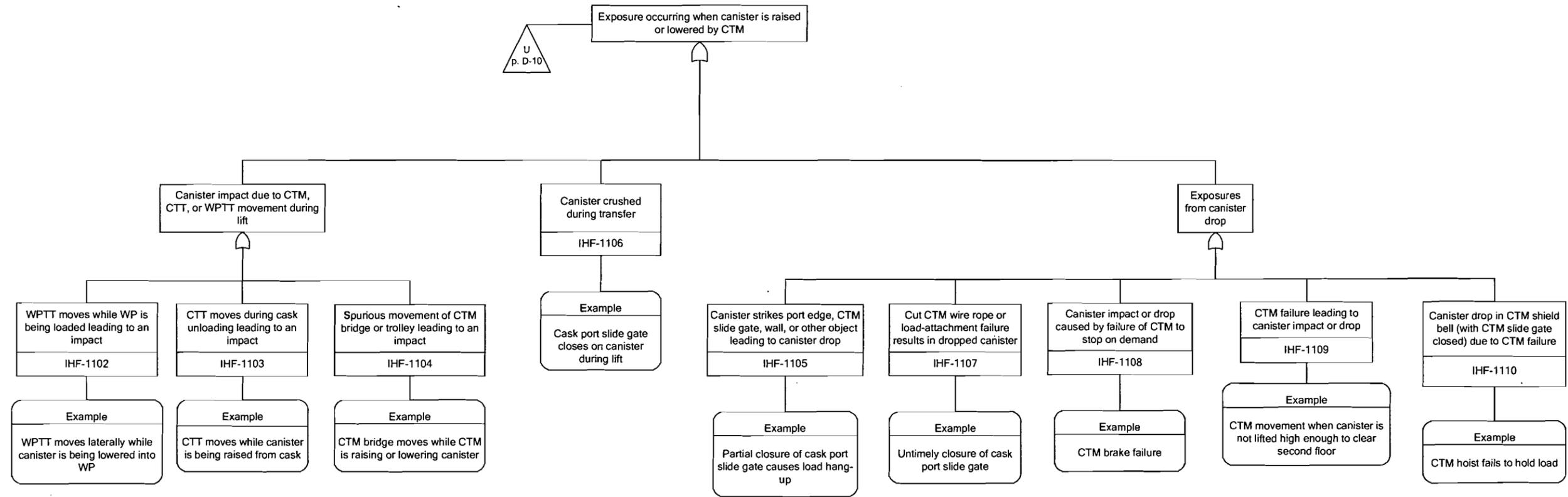
Source: Original

Table E-16. HAZOP Worksheet for Node 14

Facility/Operation: IHF				Process: WP Operation			
Node 14: Move WP to TEV (see Attachments B and C for node definitions)				Process/Equipment: WP, WPTT, TEV			
Guidewords: No, More, Less, Other Than, Reverse, As Well As, Part Of				Consequence Categories: Radioactive Release, Lack of Shielding, Criticality			
Node Item Number	Parameter	Deviation Considered	Postulated Cause	Consequence(s)	Potential Prevention/Mitigation Design of Operational Feature	Notes	MLD Index Number
14.1	WPTT Movement with Loaded WP	(Other Than) Impact or derailment	1 – Human failure 2 – Mechanical malfunction	Potential drop of or impact to WP leading to radioactive release	1 – Procedures and training 2 – Maintenance	—	IHF-1005 IHF-1006 IHF-1007 IHF-1204
14.2	Shield Door Movement	(Other Than) Failure to open shield door	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – Design of shield door-controls 3 – WP design	—	IHF-1006
14.3	Shield Door Movement	(Other Than) Closure on WPTT during transit	1 – Human failure 2 – Mechanical malfunction	Potential collision leading to radioactive release	1 – Procedures and training 2 – Design of shield-door controls 3 – WP design	—	IHF-1006
14.4	WPTT Engagement	(Other Than) Failure to secure WPTT to docking station prior to shield ring removal or WP transfer	1 – Human failure 2 – Mechanical malfunction	Potential drop of or impact to WP leading to radioactive release	1 – Procedures and training 2 – WPTT/docking station design	Potential displacement of WPTT during tilt-down or shield ring removal	IHF-1204
14.5	Shield Ring Removal	(Other Than) Not removed	Human failure	No safety consequences	—	—	—
14.6	Shield Ring Removal	(Other Than) Drops onto WP during removal	1 – Human failure 2 – Mechanical malfunction	Potential impact to WP leading to radioactive release	1 – Procedures and training 2 – Crane design	Includes installation of grapple	IHF-1202
14.7	Shield Ring Removal	(Other Than) Shield ring binds with WP during shield removal	1 – Human failure 2 – Mechanical malfunction	Potential drop of WP leading to radioactive release	1 – Procedures and training 2 – Crane design	Partial lift of WP with drop of WP	IHF-1203
14.8	Shield Ring Removal	(Less) Shield ring fails to clear WPTT or WP during shield removal	1 – Human failure 2 – Mechanical malfunction	Potential drop of or impact to WP leading to radioactive release	1 – Procedures and training 2 – Crane design	Tip-over of WPTT	IHF-1203
14.9	Down-Ending of WP in WPTT	(More) Rapid tilting rundown	1 – Human failure 2 – Mechanical malfunction	Potential impact to WP leading to radioactive release	1 – Procedures and training 2 – WPTT design	Potential ejection of WP and pallet	IHF-1204
14.10	Down-Ending of WP in WPTT	(Less or No) Stuck in mid-travel during tilting	1 – Human failure 2 – Mechanical malfunction	No safety consequences	—	—	—
14.11	Extract WP and Pallet from WPTT	(Less or No) WP and pallet stuck in WPTT	1 – Human failure 2 – Mechanical malfunction	Direct exposure	1 – Procedures and training 2 – WPTT design	Interface point with TEV and subsurface operations	IHF-1204
14.12	Extract WP and Pallet from WPTT	(More) WP and pallet extracted too rapidly from WPTT	1 – Human failure 2 – Mechanical malfunction	Potential impact to WP leading to radioactive release	1 – Procedures and training 2 – WPTT design	1 – Interface point with TEV and subsurface operations 2 – Potential collision if TEV not ready to receive	IHF-1205
14.13	Extract WP and Pallet from WPTT	(More) WP and pallet extracted before TEV doors open	1 – Human failure 2 – Mechanical malfunction	Potential impact to WP leading to radioactive release	1 – Procedures and training 2 – WPTT/TEV design	1 – Interface point with TEV and subsurface operations 2 – Potential collision if TEV not ready to receive	IHF-1205

NOTE: Guidewords "Reverse," "As Well As," and "Part Of" were not used in this node.
IHF = Initial Handling Facility; TEV = transport and emplacement vehicle; WP = waste package; WPTT = waste package transfer trolley.

Source: Original



NOTE: Unplanned exposure of individuals to radiation or radioactive materials is herein referred to as "exposure."
CTM = canister transfer machine; CTT = cask transfer trolley; IHF = Initial Handling Facility; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

Figure D-11. Exposure Occurring when Canister is Raised or Lowered by CTM