

**APPENDIX - C**  
**HAZOP SESSION SUMMARY TABLES**

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>1 - Receipt of RH Waste</b>								
1 - 1	High contamination found during survey	Human Error- Spread of contamination by shipper during loading	Potential for minimal exposure to personnel	Shipping Container- DOT Type B certified; Radiological Control procedures; ALARA (As Low As Reasonably Achievable) Program; Worker training; WAC controls; Emergency Response procedures	No Actions or Recommendations Identified (NAI)	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - 1,4	Radiological hazard only
1 - 2	Incorrect information on shipping papers	Human Error	Potential to exceed allowable storage time; Potential release due to gas generation; Potential for minimal exposure to personnel	WIPP Waste Information System procedures; Radiological Control procedures; Worker training; WAC controls;	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - 1,4	Radiological hazard only
1 - 3	Excessive storage time - Cask is left in storage too long	Human Error; Equipment Failure; Extended storage at generator	Potential release of radioactive material due to gas generation	Worker training; Waste handling procedures; WIPP Waste Information System procedures; Safety Analysis Report for Packaging (SARP) restrictions	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - 1,4	Radiological hazard only
1 - 4	High radiation - Direct radiological exposure	Human Error; Incorrect Radiological Work Permit information; Waste material shifts during shipment	Potential for direct radiological exposure to facility workers;	Radiological Control procedures (EPD's); Worker Training; ALARA Program; Dosimetry; Cask design including shielding	NAI	2,4	Facility Worker - 2,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
1 - 5	Loss of control - Transporter crashes through gate due to high speed	Human Error; Equipment Failure - Transporter brake system fails	Potential to damage the access gates; Potential to damage sections of the facility; Potential for worker injury or fatality	Drivers are trained, and qualified for proper transporter operation; Transporter is equipped with emergency brakes; Transporter maintenance provides for reliable equipment function; Access road has a 90 degree turn immediately prior to approaching the main access gate, minimum speeds achieved; Access roads are level	R-1 Verify implementation of transport truck driver training program	4,4	NA	Worker injury or fatality could result from the industrial accident (impact). No release of radiological material is postulated in this event.
1 - 6	Truck fire (inside Site gate)	Human Error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on truck; Unknown ignition source	Potential for smoke to be drawn into WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury; Potential for disruption of processing activities	Road cask design - Meets DOT Type B shipping container certification requirements; Emergency Response Procedures; Fire loading/ combustible control program; Vehicle maintenance and inspection program	R-2 Verify combustible material control program is in place.	2,4	NA	Facility worker injury could result from smoke inhalation (smoke inhalation).

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
1 - 7	Truck fire followed by an explosion (inside Site gate)	Human Error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on truck; Unknown ignition source	Potential for worker injury or fatality; Potential for significant disruption of processing activities; Potential for smoke to be drawn into WHB by ventilation system; Potential loss of exhaust filtration	Fire loading/ combustible control program; Waste Acceptance Criteria (WAC) restrictions on waste material; Emergency Response Procedures; Vehicle maintenance and inspection program; Road cask design - Meets DOT Type B shipping container certification requirements	A-1 Verify that a transport vehicle inspection program is in place  A-2 Verify combustible material control program is in place and evaluate adequacy.  A-3 Verify that the DOT testing performed to certify road cask bounds the explosion scenario	4,4	NA	Worker injury or fatality could result from the industrial accident (explosion).
1 - 8	Trailer in other than proper location - Trailer overturns	Human Error Equipment Failure	Potential for damage to road cask; Potential for fire; Potential for worker injury or fatality.	WIPP Site speed limits; Transporter driver training; Waste handling procedures; Guard rails; Road cask design - Meets DOT Type B shipping container certification requirements	R-1 Same recommendation as for 1-5. Verify implementation of transport truck driver training program	4,4	NA	Worker injury or fatality could result from the industrial accident (impact). No release of radiological material is postulated.
1 - 9	Less than adequate Preventive maintenance - Landing gear failure	Human Error	Shipping cask falls off truck; Potential for worker injury or fatality.	Shipping cask design; Truck maintenance and inspection program	R-3 Verify implementation of preventive maintenance and inspection program for trucks	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological material is postulated.

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>2 - Transfer to RH Bay</b>								
2 - 1	Truck in other than proper location - truck hits and damages tornado door hindering door closure	Human Error; Equipment Failure	Potential for significant building damage; Potential for considerable process down-time; Potential for worker injury or fatality	Waste handling procedures; Cask handling procedures; Operator training; Limited truck speed; Shipping cask design	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological material is postulated.
2 - 2	Truck in other than correct position results in fire water trench cover collapse	Human error; Mechanical failure	Loss of trailer stability;	Shipping cask design; Waste handling procedures; Driver training	R-4 Evaluate design of fire water trench cover for support capability	NA	NA	
2 - 3	Loss of control - Crane impact with road cask	Human Error; Equipment Failure	Potential to injure facility worker; Potential for slight damage to Road Cask	Limited crane speed; Crane operator training; Crane operating procedures; Crane design; Cask design - cask meets DOT Type B shipping container certification requirements; Preventive maintenance Program for crane	NAI	2,4	NA	Industrial hazard only

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
2 - 4	Diesel fire on trailer jockey (<1475°F; <30 min.)	Human Error; Improper or insufficient maintenance; Vehicle impact; Equipment Failure; Diesel fuel on trailer jockey; Unknown ignition source	Potential for smoke to be drawn through WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury; Potential for disruption of processing activities	Road cask design - Meets DOT Type B shipping container certification requirements; Emergency Response Procedures; Fire loading/ combustible control program; Vehicle maintenance and inspection program	R-2 Same Recommendation as for 1-6. Verify combustible material control program is in place  R-5 Add combustible loading limits for RH bay to FHA (Fire Hazards Analysis)	2,4	NA	Facility worker injury could result from smoke inhalation (industrial accident).
2 - 5	Diesel fire on trailer jockey followed by an explosion	Human Error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on trailer jockey; Unknown ignition source	Potential for smoke to be drawn through WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury or fatality; Potential for significant disruption of processing activities	Emergency Response Procedures; Fire loading/ combustible control program; Vehicle maintenance and inspection program; Road cask design - Meets DOT Type B shipping container certification requirements	A-4 Verify that a trailer jockey inspection program is in place  A-2 Same Action as for 1-7. Verify combustible material control program is in place and evaluate adequacy.  A-3 Same Action as for 1-7. Verify that the DOT testing performed to certify road cask bounds the explosion scenario	4,4	NA	Worker injury or fatality could result from the industrial accident (explosion).

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq)	Radiological Rank (Cons.,Freq)	Comments
<b>3 - Cask preparation</b>								
3 - 1	Loss of control - Crane impact with road cask See 2-3	Human Error; Mechanical Failure	Potential damage to cask during removal of impact limiter; Potential for worker injury	Limited crane speed; Crane operator training; Crane handling procedures; Crane design; Cask design - Cask meets DOT Type B shipping container certification requirements; Preventive Maintenance Program for crane	NAI	2,4	NA	Industrial hazard only
3 - 2	Cask dropped during crane lift	Human Error (1) hold downs not released, (2) hit obstacle, (3) catch rigging on car and tips the car over Mechanical Failure - Crane/Rigging	Potential for significant damage to equipment; Potential for worker injury or fatality.	Limited crane speed; Limited lift height; Crane operator training; Crane operating procedures; Crane design; Cask design - Cask meets DOT Type B shipping container certification requirements; Preventive maintenance program for crane	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident.
3 - 3	High air activity - Airborne release during cask preparation activities (includes: 1)Head space gas sampling (outer) 2)Removing outer lid 3)Head space gas sampling (inner) 4)Installing inner lid Pintle	Equipment Failure - Leak in canister (O-ring); Human error - Canister not properly decontaminated prior to placement in road cask	Potential for minimal worker exposure; Potential spread of contamination into facility	Air sampling procedures; Radiological Control procedures; ALARA Program; Waste handling procedures	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite -NA	Radiological hazard only

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
3 - 4	Crane drops outer lid onto cask	Human Error; Equipment Failure - Crane	Potential damage to cask; Potential damage to inner container (ICV) lid; Potential damage to outer lid sealing surface; Potential for severe worker injury	Cask design; Crane operator training; Waste handling procedures; Cask (ICV lid) design; Lifting fixture design	NAI	3,4	NA	Industrial hazard only
<b>4 - Cask transfer to unloading room</b>								
4 - 1	Over-speed - Impact involving transfer car with road cask - transfer car stays on rails	Human Error; Equipment Failure; foreign object on rails	Potential production downtime; Potential for damage to equipment; Potential for severe worker injury	Transfer car design; Rail design; Cask design; Operator training; Waste handling procedures; Limited transfer car speed	NAI	3,4	NA	Industrial hazard only
4 - 2	Road cask transfer car derails and falls over	Human Error - Failure to replace removable rails at cask unloading room entry; Foreign object on rails	Potential for production downtime; Potential for worker injury or fatality	Road Cask transfer car design; Cask/canister design; Operator training; Waste handling procedures;	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident.

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>5 -Road cask transfer to shuttle car</b>								
5 - 1	Road cask dropped in the cask unloading room	Human Error; Equipment Failure - Crane	Potential for production downtime; Potential for equipment damage; Potential for worker injury or fatality	Cask/canister design; Operator training; Waste handling procedures; Room design limits height of lift	R-6 Evaluate the HVAC (Heating, Ventilation, and Air Conditioning) DP's (Differential Pressures) with road cask unloading room door open.  A-5 Verify that operating procedures exclude personnel from room during cask transfer for worker protection	4,4	NA	Worker injury or fatality could result from the industrial accident.
5 - 2	Road cask dropped into transfer cell through the floor port	Human Error; Equipment Failure (mechanical); Control Loop Failure-PLC (Programmable Logic Control)	Potential for production downtime; Potential for equipment damage; Potential for worker injury or fatality.	Cask/canister design; Operator training; Waste handling and transfer cell procedures (entry restrictions); Interlocks involving floor valve, shuttle car, crane (protects against worker error); Impact limiter on canister; Shuttle car design	R-6 Same Recommendation as for 5-1: Evaluate the HVAC DP's with road cask unloading room door open.	4,4	NA	Worker injury or fatality could result from the industrial accident.
5 - 3	Equipment performs in other than desired mode - Shield valve interlocks fail such that both shield valves can be open at the same time	Equipment Failure; Control Loop Failure-PLC (Programmable Logic Control)	Potential for air flow reversal (minimal)	Periodic functional checks of control loop	NAI	NA	NA	

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
5 - 4	Excessive movement - Shuttle car moves while road cask is being lowered into shuttle car	Human Error; Equipment Failure; Control loop failure	Potential equipment damage; Potential for processing delays	Operator training related to transfer operations; Periodic functional checks of control loop; Shuttle car/crane interlock; Road cask design - Meets DOT Type B shipping container certification requirements	R-7 Evaluate this scenario and consider potential need for other engineering safeguards	NA	NA	
5 - 5	Lack of attention - Individual falls through road cask unloading room floor port	Human Error	Potential for worker injury or fatality.	Transfer procedures; Operator training/qualification program	R-8 Install restraint at floor valve opening	4,4	NA	Worker injury or fatality could result from the industrial accident.
5 - 6	Floor valve closes too soon (Sooner than required time)	Equipment Failure Control Loop Failure-PLC (Programmable Logic Control)	Potential damage to cask; Potential damage to crane ropes; Potential damage to floor valve	Hoist interlock; Cask Design; Periodic functional checks of control system	NAI	NA	NA	No release of radioactive material

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>6 - Move cask to position in transfer cell - remove inner lid</b>								
6 - 1	Shuttle failure causes cask to drop to transfer cell floor (Lack of equipment integrity)	Equipment Failure; Metal fatigue; failure to perform periodic maintenance	Potential for production downtime; Potential for personnel exposure caused by inner lid coming off; Potential for worker injury or fatality.	Shuttle and shuttle support design; Limited access into Transfer Cell; Shuttle operation procedures; Operator training; Cask and canister design	R-9 Verify Preventive Maintenance Program is in place for shuttle  R-10 Evaluate dynamic forces on shuttle car in engineering design	4,4	Facility Worker - 2,4  Onsite Worker - 1,4  Offsite -NA	Worker injury or fatality could result from industrial accident. Potential for minor radiological impact to facility worker
6 - 2	Equipment performs in other than desired mode - Floor valve at road cask unloading room fails to close	Equipment Failure - floor valve malfunction; Control Loop Failure-PLC (Programmable Logic Control)	Potential for air flow reversal (minimal);	Periodic functional checks of control loop; Preventive Maintenance program for floor valve	NAI	NA	NA	No release of radioactive material
6 - 3	Drop of inner Road Cask lid on canister	Human Error; Control Loop Failure Mechanical Failure	Potential minor damage to canister	Canister design (DOT 7A Type A certified container); Pre-operational checks; Preventive Maintenance Program	NAI	NA	NA	No release of radioactive material
6 - 4	Other than desired position - shuttle moves while removing Road Cask inner lid	Mechanical Failure; Human error; Control loop failure	Potential for minor equipment damage	Shuttle operation procedures; Operator training; Shuttle car/crane interlock	NAI	NA	NA	No release of radioactive material

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
6 - 5	Incorrect position of shield valves ( valves close sooner than desired)	Equipment Failure; Control Loop Failure-PLC (Programmable Logic Controller)	Potential damage to cask; Potential damage to crane ropes; Potential damage to floor valve;	Hoist interlock; Cask design	NAI	NA	NA	No release of radioactive material
<b>7 - Load canister into facility cask</b>								
7 - 1	Excessive movement - Shuttle moves while crane is lifting canister	Mechanical Failure; Control Loop Failure	Potential for damage to shuttle; Potential breach of the canister; Potential spread of contamination; Potential for direct radiological exposure to personnel; Potential for worker injury or fatality.	Grapple hoist interlock; Limited access into Transfer Cell; Pre-operational checks; Preventive Maintenance Program for shuttle and control equipment; Waste handling procedures; RH area ventilation system - HEPA (High Efficiency Particulate Air) filtration	R-11 Review canister and shuttle car designs and control loop design to ensure potential for inadvertent movement is addressed	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker injury or fatality could result from the industrial accident. Potential for radiological impact to facility, and to receptors onsite including in facility and offsite.
7 - 2	Canister is dropped while being lifted into facility cask; canister falls back into road cask or onto transfer room floor	Human Error; Equipment Failure - Crane, grapple; Control Loop Failure;	Potential breach of canister; Potential spread of contamination; Potential for significant damage to facility; Potential for considerable consequences to offsite individuals; Potential for significant process downtime for recovery; Potential for worker injury or fatality.	HEPA filtration; Waste handling and crane operation procedures; Operator training; Weight interlock on grapple; Shielding for workers; Impact limiter on canister; Pre-operational checks for crane and control equipment; Preventive Maintenance Program for crane equipment and control equipment; Limited access into transfer cell		4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker injury or fatality could result from the industrial accident. Potential for radiological impact to offsite

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7 - 3	Canister drop after lifting into facility cask, canister falls onto transfer cell shield valve.	Human Error; Equipment Failure - Crane, grapple; Control loop failure;	Potential for damage to equipment	Canister design; Waste handling and crane operation procedures; Operator training; Control panel shielding for workers; Facility cask shielding; Pre-operational checks for crane and control equipment operation; Preventive Maintenance Program for crane and control equipment	NAI	NA	NA	No release of radioactive material
7 - 4	Equipment performs in other than desired mode - Telescoping port shield retracts during transfers	Control Loop Failure	Potential for direct radiological exposure to personnel	Control loop interlock; Fail safe design of port shield; Pre-operational checks; Preventive Maintenance Program; Shielding for operator at control panel	NAI	2,4	Facility Worker - 2,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only
7 - 5	Uncontrolled lift raises shield bell exposing canister	Control Loop Failure	Potential for direct radiological exposure to personnel	PLC interlock with facility cask top shield valve; Pre-operational checks; Preventive Maintenance Program; Shielding for operator at control panel	NAI	2,4	Facility Worker - 2,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only
7 - 6	Shield valves (2) close on canister (sooner than desired)	Control Loop Failure	Potential breach of canister; Potential spread of contamination; Potential for direct radiological exposure to personnel; Potential for radiological impact offsite	HEPA filtration; Pre-operational checks ; Preventive Maintenance Program; Shielding for workers; Control loop interlocks; Torque limiters on close of shield valves; Differential pressures maintained by HVAC system	R-12 Evaluate impact of closing shield valve while moving shuttle car to monitoring position in transfer cell  R-13 Evaluate adequacy of recovery procedures	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological hazard only

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
7 - 7	Facility cask lower shield valve opens while canister is sitting on it (at other than desired time)	Control Loop Failure	Potential to drop canister to transfer cell shield valve; Potential for equipment damage; Potential for production downtime	Lower shield valve interlock with grapple position and weight; Interlock with transfer cell shield valve; Lock pins; Pre-operational checks; Preventive Maintenance Program for control equipment; Canister design	NAI	NA	NA	No release of radioactive material
7 - 8	High contamination on road cask after canister removed	Human Error- Contaminated at shipping site; Canister breach (loss of primary confinement)	Potential for spread of contamination to facility; Potential for contamination of personnel	Shipping criteria; HEPA filtration; Transfer cell design; Radiological control procedures; Cask head space sample taken during Road Cask preparation step	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only. Minimal impact to facility and workers
7 - 9	Wrong canister ID with respect to shipping papers	Human Error - Generator Site Error	Operational delay (Negligible impact); Potential to exceed storage time limits for canister	WIPP Waste Information System procedures	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only. Minimal impact to facility and workers

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
7 - 10	Hydraulic fluid fire	Leak of hydraulic fluid from facility cask rotating device; Unknown Ignition Source	Potential for damage to facility cask and other equipment (air hose, power cables); Potential adverse impact to ventilation system; Potential for generation of toxic fumes; Potential worker injury from smoke inhalation	Limited quantity (approximately 40 gallons) of hydraulic fluid; Smoke alarms; Sprinkler system; Evacuation plan for Facility Cask loading room; Emergency exit from Facility Cask loading room; Sump in room	R-14 Add combustible loading limits for waste handling building to FHA	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Facility worker injury could result from smoke inhalation (industrial accident). Minimal potential for radiological impact.
7 - 11	Incorrect sequence - Cask is rotated to horizontal position before shield valves are closed with grapple still attached	Control Loop Failure	Potential for direct radiological exposure to personnel	Interlocked to grapple hoist position; Grapple design will not release; Physical restraints to keep canister in place; Pre-operational checks for control system; Preventive Maintenance Program for control system; Shielding for operator at control panel	R-15 Verify rotating equipment design will preclude radiological exposure as a result of this event.	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite -NA	Radiological hazard only. Minimal impact to facility and workers
7 - 12	Excessive movement - Facility cask rotates freely during rotation to horizontal position	Human Error; Mechanical Failure	Potential equipment damage	Pre-operational checks for rotation equipment function; Mechanical design of facility cask transfer car prevents over-rotation;	NAI	NA	NA	No release of radioactive material

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
7 - 13	Unwanted motion - Facility cask transfer car moves while rotating Facility Cask	Human Error; Mechanical Failure	Potential equipment damage	Motion interlocks; Equipment handler training; Operating procedures for Facility cask handling;	NAI	NA	NA	No release of radioactive material
<b>8 - Facility cask loaded onto conveyance</b>								
8 -1	Facility cask transfer car moved while turntable misaligned (movement at incorrect time)	Human Error Equipment Failure	Potential equipment damage - turntable, facility cask transfer car; Potential for process downtime	Mechanical design of transfer car; Limited speed; Operator Training; Transfer car movement procedures; Pre-operational checks; Preventive Maintenance Program	NAI	NA	NA	No release of radioactive material
8 - 2	Cask loading room door damaged from impact of facility cask transfer car	Human Error; Equipment Failure - Facility cask drive mechanism	Potential delay of process; Potential for considerable damage to facility; Potential to lose differential pressure in some areas of facility; Potential for air flow reversal	Operator Training/Procedures; Preventive Maintenance Program	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - 1,4	Minimal radiological hazard could exist as the result of the air flow reversal if there is contamination present in the facility
8 - 3	Incorrect conveyance position - Conveyance misalignment at the collar slab	Control Loop Failure; Equipment failure	Inability to load facility cask car onto conveyance; Potential for damage to pivot rails; Minor equipment damage	Pre-operational checks; Preventive Maintenance Program; Equipment design; Equipment Inspection program	NAI	NA	NA	No release of radioactive material

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Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
8 - 4	Incorrect conveyance position - Conveyance positioned at station, facility cask dropped into shaft	Human Error	Major damage to shaft; Potential breach of container; Potential for major release of radioactive materials; Potential for significant radiological exposure to personnel; Potential for considerable impact offsite; Potential worker injury or fatality	Pivot rail stops; Car stops; Training/Procedures Shift to HEPA filtration Physical barriers-shaft gates; Limited speed of Facility cask transfer car; Redundant verification of equipment readiness; Pivot rails interlocked to hoist position (hardwired); Cask unloading room doors	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker injury or fatality could result from the industrial accident (dropped cask). Radiological release would likely be extensive
8 - 5	Farther than desired position - Facility cask transfer car over- traveled onto conveyance	Human Error	Potential equipment damage	Power cable length is limited; Facility cask movement procedures; Pivot rail alignment; Door interlocks; Automatic stop - Facility cask transfer car	NAI	NA	NA	No release of radioactive material

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8 - 6	Loss of brakes on conveyance while loaded with facility cask - Conveyance drops to bottom of waste shaft	Equipment Failure -Brake system	Major damage to shaft; Potential breach of container; Potential for major release of radioactive materials; Potential for significant radiological exposure to personnel; Potential for considerable impact offsite; Potential worker injury or fatality	Brake system design; Hoist equipment inspection program; Pre-operational checks; Preventive maintenance program on hoist including brake system	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker injury or fatality could result from the industrial accident (dropped conveyance with cask). Radiological release would likely be extensive
8 - 7	Less than desired stability - Facility cask transfer car not latched to conveyance	Human Error	Potential damage to shaft and conveyance; Potential for process downtime	Operator training; Operating procedures; Drive train requires power to move - (gear driven)	NAI	NA	NA	No release of radioactive material
<b>9 - Facility cask transfer to disposal room</b>								
9 - 1	Incorrect sequence - Pivot rails not lowered while trying to move Facility cask transfer car from conveyance	Human Error	Potential for minor damage to transfer car and conveyance; Potential for minor damage to pivot rails	Operator Training; Conveyance operating procedures	NAI	NA	NA	No release of radiological materials

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9 - 2	Incorrect position - Misalignment of conveyance with pivot rails	Human Error	Potential for minor damage to transfer car and conveyance; Potential for minor damage to pivot rails	Operator Training; Conveyance operating procedures	NAI	NA	NA	No release of radiological materials
9 - 3	Derailment of Facility cask transfer car	Equipment Failure - Rail; Foreign object on rails	Potential to turn car over; Potential equipment damage- facility cask and/or rail; Considerable operating downtime; Potential worker injury or fatality	Preventive Maintenance Program for rails; Operator training program; Transfer car design; Operating procedures - limited speed of transfer car; Cask design	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological materials.
9 - 4	Loss of control - Forklift impacts Facility cask while in process of lifting cask	Human Error; Equipment Failure - Forklift brake malfunction	Potential to turn transfer car over; Potential equipment damage- facility cask and/or forklift; Potential for considerable process downtime; Potential worker injury or fatality	Forklift operator training; Preventive Maintenance Program for forklift (includes brake system); Cask design - limits cask damage	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological materials.
9 - 5	Forklift drops facility cask	Human Error; Forklift collision; Equipment Failure - forklift hydraulic system, structural failure of fork tines.	Potential for canister breach Potential equipment damage - facility cask, rail, and/or forklift; Potential worker injury or fatality	Preventive Maintenance Program on forklift; Forklift inspection program; Waste transit notification program; Forklift operator training; Operating procedures;	A-6 Verify Facility cask integrity in the event of a corner drop	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker injury or fatality could result from the industrial accident.

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9 - 6	Loss of control - Forklift collision - general (No drop of Facility cask)	Human Error - Other vehicles collide with forklift; Mechanical failure	Potential equipment damage; Potential facility damage; Potential for damage to underground ventilation system; Potential worker injury or fatality	Traffic controls underground; Forklift training program; Operating procedures; Waste transit notification program; Preventive Maintenance Program on forklift; Facility cask design	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological materials.
9 - 7	Diesel fire on forklift	Diesel fuel leak; Unknown Ignition Source	Potential for damage to Facility cask and canister; canister breach; Potential for significant radiological exposure to personnel; Potential worker injury or fatality	Vented canister; Fire suppression system (on forklift); Underground ventilation system; Rescue program; Mine worker training; Mine evacuation plan	A-7 Verify that the fire response plan addresses this event  R-16 Investigate the hydrogen generation (through radiolysis) in the vicinity of emplacement activities	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	Worker fatality could occur as the result of the fire (industrial safety issue). Radiological impact could be considerable due to facility cask not being qualified for fire.
9 - 8	Diesel fire followed by explosion	Diesel fuel leak; Unknown Ignition Source	Potential for radiological exposure to personnel; Potential for damage to facility cask and canister; Potential for canister breach; Potential worker injury or fatality; Potential for significant damage to facility; Potential for significant adverse impact to facility operations	Vented canister; Fire suppression system (on forklift); Underground ventilation system; Rescue program; Mine worker training; Mine evacuation plan	A-7 Same Action as for 9-7. Verify that the fire response plan addresses this event  R-16 Same recommendation as for 9-7. Investigate the potential for hydrogen generation (through radiolysis) in vicinity of emplacement activities	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	Worker fatality could occur as the result of the explosion (industrial safety issue). Radiological impact could be considerable due to facility cask not withstanding the impact

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>10 - Canister emplacement in borehole</b>								
10-1	Loss of control - Forklift drops Facility cask onto emplacement equipment	Human Error; Equipment Failure	Potential for damage to emplacement equipment; Breach of the waste cannister, Personnel Exposure, Release to the environment, Potential for processing delays	Equipment design	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	
10-2	Hydraulic fluid/diesel fuel fire	Hydraulic fluid or diesel fuel leak; Unknown Ignition Source	Potential for radiological exposure to personnel; Potential for damage to facility cask and canister; Potential for canister breach; Potential worker injury or fatality	Vented canister; Fire suppression system (on forklift); Underground ventilation system; Rescue program; Mine worker training; Mine evacuation plan	A-7 Same Action as for 9-7. Verify that the fire response plan addresses this event  R-16 Same recommendation as for 9-7. Investigate the potential for hydrogen generation (through radiolysis) in vicinity of emplacement activities	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Worker fatality could occur as the result of the fire (industrial safety issue). Radiological impact could be considerable due to facility cask not being qualified for fire

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
10-3	Hydraulic fluid/diesel fuel fire followed by an explosion	Hydraulic fluid or diesel fuel leak; Unknown Ignition Source;	Potential for radiological exposure to personnel; Potential for damage to facility cask and canister; Potential for canister breach; Potential worker injury or fatality; Potential for significant damage to facility; Potential for significant adverse impact to facility operations	Vented canister; Fire suppression system (on forklift); Underground ventilation system; Rescue program; Mine worker training; Mine evacuation plan	A-7 Same Action as for 9-7. Verify that the fire response plan addresses this event  R-16 Same recommendation as for 9-7. Investigate the potential for hydrogen generation (through radiolysis) in vicinity of emplacement activities	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	Worker fatality could occur as the result of the explosion (industrial safety issue). Radiological impact could be considerable due to facility cask not withstanding the impact
10-4	Incorrect position - Shield collar misalignment with facility cask	Equipment Failure; Control Loop Failure	Potential for direct radiological exposure to personnel	Control loop design; Multiple position sensors; Multiple level sensors; Pre-operational checks; Preventive Maintenance Program for emplacement equipment; Emplacement equipment design; Operator Training; Operating Procedures Physical lock between shield collar and Facility cask; Control panel indicator identifies misalignment	NAI	1,4	Facility Worker - 1,4  Onsite Worker - 1,4  Offsite - NA	Radiological hazard only. A minimal radiological exposure hazard could exist in this event

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
10-5	Shield valve on emplacement equipment is closed on canister during emplacement process (mis-positioned shield valve; movement sooner than desired)	Control Loop Failure; Mechanical failure on emplacement equipment	Potential damage to canister; Potential breach of canister; Potential release of radioactive material; Potential for direct radiological exposure to personnel; Potential for adverse impact offsite	Shield valve control interlocks; Torque limiter on shield valve motor; Shift to HEPA filtration Control panel indicator signals shield valve problem; Radioactive material confined by emplacement equipment; Pre-operational checks; Preventive Maintenance Program for emplacement equipment	NAI	3,4	Facility Worker - 3,4 Onsite Worker - 2,4 Offsite - 2,4	Radiological hazard only. This event could result in considerable radiological impact to facility workers
10-6	Mis-alignment of canister as it is moved into borehole	Human Error; Equipment Failure- Emplacement equipment settles and results in misalignment; Equipment Failure - level indicator malfunction	Potential damage to canister; Potential breach of canister; Potential damage to emplacement equipment; Potential release of radioactive material; Potential direct radiological exposure to personnel; Potential for adverse impact offsite;	Operator training; Waste handling (emplacement) procedures; Stall pressure limit on ram; Emplacement equipment is braced; Polyethylene liner installed into borehole to reduce friction and limit potential for interference with canister emplacement; Shift to HEPA filtration	NAI	3,4	Facility Worker - 3,4 Onsite Worker - 2,4 Offsite - 2,4	Radiological hazard only. This event could result in considerable radiological impact to facility workers
10-7	Roof Collapse during emplacement activities	Room walls, roof shift	Potential for worker injury or fatality; Potential for disruption of processing operations;	Facility cask design; Canister design; Emplacement equipment design; Motion detection instrumentation; Emergency response procedures; Room inspection program	NAI	4,4	NA	Worker injury or fatality could occur as the result of the roof collapse (mining safety issue); no radiological release is expected.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>11- Decontamination Activities</b>								
1) Receipt 2) Cask prep 3) Canister transfer (worst case) 4) Post emplacement								
11-1	High contamination - Surface contamination found during normal operation	Loss of primary confinement; Human Error- Spread of contamination by shipper during loading	Potential spread of contamination and airborne radioactivity to worker	Radiological Work Permit; Worker training; Personal Protective Equipment; Shift to HEPA filtration	NAI	1,4	Facility Worker - 1,4  Onsite Worker - 1,4  Offsite - 1,4	Radiological hazard only. A minimal radiological exposure hazard could exist in this event
<b>12 - CH/ RH Interface</b>								
12-1	Equipment performs in other than desired mode - CH/RH conveyance loading doors open at same time	Human Error - Interlocks which prevent simultaneous opening of doors are inadvertently bypassed; Control loop malfunction	Potential diversion of exhaust path through underground vs. through RH HVAC system	HEPA- Underground Worker training; Waste handling procedures; Preventive Maintenance Program for control equipment; Scheduling of CH and RH operations	NAI	NA	NA	No release of radiological materials
12-2	Loss of control - Underground transporting vehicle collision	Human Error- Other drivers run into forklift; Mechanical failure	Potential equipment damage; Potential facility damage; Potential for damage to underground ventilation system; Potential worker injury or fatality	Traffic controls underground; Forklift training program; Waste handling procedures; Waste transit notification program; Preventive Maintenance Program on vehicles	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological materials.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
12-3	Loss of ventilation (ventilation requirements between RH and CH processes are not maintained)	Human Error- Improper bulkhead alignment Equipment Failure - Failure of exhaust fans; Utility Failure - Loss of power	Potential to shutdown operations	Underground ventilation system alignment procedures; Worker training; Preventive Maintenance Program for ventilation system equipment; Redundant exhaust fans; Evacuation plan	NAI	NA	NA	No release of radiological materials
<b>13 - General Facility operation - NPH, External events</b>								
13-1	Seismic Event (Design Basis Earthquake)	Earthquake	Potential for major disruption of facility operations; Potential damage to cask and/or canister; Potential breach of canister; Potential for loss of site utilities; Potential to release radioactive material; Potential for radiological exposure to offsite personnel; Potential for fire; Potential for explosion; Potential for worker injury or fatality	Waste Handling Building designed for DBE; Emergency Response Plan; Recovery Plan; Road cask design - meets DOT Type B shipping container certification requirements; HVAC system shutdown switch	NAI	4,3	Facility Worker - 4,3 Onsite Worker - 4,3 Offsite - 4,3	Worker injury or fatality could occur as the result of the earthquake alone. Radiological impact would likely be extensive.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
13-2	Tornado (Design Basis Tornado)	Tornado	Potential for disruption of processing operations; Potential to lose site utilities; Potential for worker injury or fatality; Potential for fire; Potential for explosion	Waste Handling Building designed to withstand tornados; Emergency response procedures; Recovery Plan; Weather monitored by CMR (Central Monitoring Room); Road cask design - meets DOT Type B shipping container certification requirements;	NAI	4,4	NA	Worker injury or fatality could occur as the result of the tornado.
13-3	Loss of Facility ventilation	Human Error- Improper bulkhead alignment Equipment Failure -Failure of exhaust fans; Loss of electrical power; Loss of compressed air	Potential to shutdown operations	Worker training; Ventilation system operating procedures; Preventive Maintenance Program for ventilation system equipment; Redundant Exhaust fans; Evacuation plan; Backup diesel generators; Redundant air compressors	NAI	NA	NA	No release of radiological materials
13-4	Loss of power	NPH - Earthquake, tornado, lightning, high winds, etc.; Vehicle impact; Power from commercial supplier is lost	Potential loss of filtered ventilation; Potential loss of hoist	Backup diesel generators; Redundant power feeds; Response procedures; Worker training	NAI	NA	NA	No release of radiological materials

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
13-5	Loss of Fire Protection (includes detection and suppression)	NPH; Loss of 180,000 gallon fire water storage tanks	Potential inability to detect and suppress fires	Design and construction of fire suppression system; Two on-site fire water storage tanks containing 180,000 gallons (One storage tank capacity sufficient for DBF); Two fire pumps, one electrical and one diesel, available; On-site fire truck and fire fighting equipment All fire related systems, training, inspection, and testing are in accordance to NFPA (National Fire Protection Association) and NEC regulations Inspections and functional tests of system performed on a periodic basis 24 hour battery backup for fire detection system available in WHB; 24 hour fire brigade	NAI	NA	NA	Ranking would be significant only if there were a fire event and the detection and suppression systems were inoperative. Otherwise, loss of the detection and suppression systems has no impact.
13-6	Range Fire	Lightning; unknown ignition source Gas pipeline explosion	Potential to disrupt site operations; Potential for smoke to enter the mine shaft; Potential for underground evacuation; Potential for smoke to enter facility buildings; Potential for facility damage	Emergency response procedures; Fire break installed; Fire fighting capability Emergency response team; Fire fighting training; 24 hour fire brigade	NAI	2,4	NA	Industrial accident only. Potential for a range fire having a direct impact on the WHB such that a radiological release would occur is minimal

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
13-7	Aircraft Crashes Into WHB	Personnel error; Equipment failure	Major damage to WHB; Potential for fire; Potential for worker injury or fatality Potential for major release of radioactive material; Potential for considerable radiological exposure to personnel	Physical location of site is remote; Air space above facility is not part of normal flight patterns; Physical size of WHB	NAI	4,1	Facility Worker - 4,1 Onsite Worker - 4,1 Offsite - 4,1	This event would have major radiological and non-radiological impact. However, the event is beyond extremely unlikely and does not require accident analysis. Worker injury or fatality could result from the industrial accident.
13-8	Gas Pipeline Explosion	Loss of pipe integrity, spark Natural gas explosion Range Fire	Potential for fire Potential for off-site personnel injury or fatality Potential environmental concern Potential for adverse media attention Potential to stop site operations	WHB is located one mile from nearest pipeline. Damage radius from recent explosions is a few hundred feet	NAI	2,4	Facility Worker - 0,4 Onsite Worker - 0,4 Offsite -0,4	The offsite personnel would have to be in the right location at the wrong time, and the chances of that occurring are the same as they are for the average citizen.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
13-8	Cold Weather Natural Ventilation Pressure results in changes to air balance (Underground ventilation system)	Cold weather caused Natural Ventilation Pressure (NVP)	Potential to disrupt waste handling operations; Potential to, in the event of an accident involving release of radiological material, spread airborne contamination to the environment; Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt Potential for waste shaft hoist to fail; Potential for worker injury	Operator training and qualification; Waste shaft hoist system design; Operating procedures; Air balance and flow tests; Shaft pressure monitoring; Alarms to indicate adverse air pressure conditions; WIPP ventilation simulator used for guidance; Underground ventilation remote monitoring control system (monitors air flows and d/p's and enable CMR operator to adjust vortex to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure); Isolation of mine splits; Backup power available to operate fans for flow through the panel area	NAI	3,4	NA	There would be no radiological hazard as the result of the cold weather NVP event unless there was already contamination present in the mine. Injury to worker related to industrial mining safety.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
13-9	Hot Weather Natural Ventilation Pressure results in changes to air balance (Underground ventilation system)	Hot weather caused Natural Ventilation Pressure (NVP)	Potential to disrupt waste handling operations; Potential to, in the event of an accident involving release of radiological material, spread airborne contamination to the environment; Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt Potential for waste shaft hoist to fail; Potential for worker injury	Operator training and qualification; Waste shaft hoist system design; Preventative maintenance procedures; Air balance and flow tests; Monitoring at bulkhead 309; Bulkhead 309 redesign (recent) to pressurize the chamber between the walls of the 309 bulkhead using fans; Procedures to maintain differential pressures in the mine; WIPP ventilation simulator used for guidance; Underground ventilation remote monitoring control system (monitors air flows and d/p's and enables CMR operator to adjust vortex to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure); Isolation of mine splits; Backup power available to operate fans for flow through the panel area; Alarms to indicate adverse air pressure conditions	NAI	3,4	NA	There would be no radiological hazard as the result of the hot weather NVP event unless there was already contamination present in the mine. Injury to worker related to industrial mining safety.

Table 1- 72B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions or Recommendations	Total Rank (Cons.,Freq )	Radiological Rank (Cons.,Freq)	Comments
<b>14 - Storage Mode</b>								
14-1	Borehole shrinks over time before panel closes, crushing canister	Salt around borehole shifts and seals around canister	Potential breach of canister; Potential release of radioactive material; Potential personnel exposure; Potential spread of contamination to adjacent areas;	Shift to HEPA filtration; Room closure system; Canister design	NAI	2,4	Facility Worker - 2,4 Onsite Worker - 1,4 Offsite - 1,4	Radiological hazard only; a minor radiological exposure hazard for facility workers.
14-2	Buildup of explosive gas in closed room	Generation of Methane, or Hydrogen gas from Transuranic (TRU) waste material exceeds expected values	Potential to exceed VOC emission thresholds per RCRA/NMED (Resource Conservation and Recovery Act/ New Mexico Environmental Department) Potential for fire; Potential for explosion; Potential to release radioactive material; Potential for personnel injury or fatality;	Panel Closure systems; Backfill (limits propagation); Closed panel isolated from ventilation; Waste Acceptance Criteria; Shift to HEPA filtration	NAI	4,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - 1,4	Worker fatality could occur as the result of an explosion (mining safety event). Radiological exposure hazard is expected to be minimal.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>1. Cask Receipt and Transfer to RH Bay</b>								
1A-1	Higher than expected contamination is found when inspecting trailer and 10-160B Cask at the gate prior to entry on site	Shipment discrepancy; Movement of waste during traveling.	Potential for minimal exposure to facility worker	Survey at the gate - Radiological Control procedures; Shipping Container - DOT Type B certified; WAC Requirements; Inspection and survey in transit; Personnel Protective Equipment.	No Actions Identified (NAI)	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	Radiological hazard only
1A-2	Shipping Manifest Discrepancy	Human error	Potential for loss of production; Possible return of shipment	WIPP Waste Information System Procedures; Radiological Control procedures; Worker training; WAC controls.	A-1 ) Check with transportation to verify procedures for checking manifest prior and during transport	1,4	NA	Note: Check the Program Implementation Guide with the States - Rebecca Walker or Jeff Winkle.
1A-3	Excessive storage time - Cask is left in storage too long	Human error; Equipment failure; Extended storage at generator	Potential release of radioactive material due to gas generation	Worker training; Waste handling procedures; WIPP Waste Information System procedures; Safety Analysis Report for Packaging (SARP) restrictions.	NAI	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	Radiological hazard only
1A-4	High radiation - Direct radiological exposure	Human error; Incorrect Radiological Work Permit information; Waste material shifts during shipment	Potential for direct radiological exposure to facility workers	Radiological Control procedures (EPD's); Worker Training; ALARA Program; Dosimetry; Cask design including shielding; Inspection and survey in transit.	NAI	2,4	Facility Worker - 2,4 Onsite Worker - 1,4 Offsite - NA	Radiological hazard only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
1A-5	Loss of control - Transporter crashes through gate due to high speed	Human error; Equipment failure - transporter brake system fails	Potential to damage the access gates; Potential to damage sections of the facility; Potential for worker injury or fatality	Drivers are trained, and qualified for proper transporter operation; Transporter is equipped with emergency brakes; Transporter maintenance provides for reliable equipment function; Access road has a 90 degree turn immediately prior to approaching the main access gate, minimum speeds achieved; Access roads are level.	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident (impact). No release of radiological material is postulated in this event.
1A-6	Tractor trailer truck fire (inside Site gate and outside of WHB)	Human error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on truck; Unknown ignition source	Potential for smoke to be drawn into WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury; Potential for disruption of processing activities	10-160B Cask design - Meets DOT Type B shipping container certification requirements; Emergency Response Procedures; Fire Loading/ Combustible Control Program; Vehicle Maintenance and Inspection Program.	NAI	2,4	NA	Facility worker injury could result from smoke inhalation.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
1A-7	Tractor trailer truck fire followed by an explosion (inside Site gate and outside WHB)	Human error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on truck; Unknown ignition source	Potential for worker injury or fatality; Potential for significant disruption of processing activities; Potential for smoke to be drawn into WHB by ventilation system; Potential loss of exhaust filtration	Fire Loading/ Combustible Control Program; Waste Acceptance Criteria (WAC) restrictions on waste material; Emergency Response Procedures; Vehicle Maintenance and Inspection Program; 10-160B Cask design - Meets DOT Type B shipping container certification requirements.	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident (explosion).
1A-8	Trailer in other than proper location - Trailer overturns	Human error Equipment failure	Potential for damage to cask; Potential for fire; Potential for worker injury or fatality.	WIPP Site speed limits; Transporter driver training; Waste handling procedures; Guard rails; 10-160B Cask design - Meets DOT Type B shipping container certification requirements.	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident (impact). No release of radiological material is postulated.
1A-9	Less than adequate preventive maintenance - Landing gear failure	Human error	Shipping cask falls off truck; Potential for worker injury or fatality.	Shipping cask design; Truck maintenance and Inspection Program.	NAI	4,4	NA	Worker injury or fatality could result from the industrial accident. No release of radiological material is postulated.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
1B-1	Fire water trench grate fails and trailer shifts as the trailer backs into RH Bay	Human error	Potential for equipment damage; Potential to drop the cask in the RH Bay; Potential for personnel injury	Procedures and training; Spotters; Trailer and cask design; Cask design can withstand up to 40ft.	NAI	4,4	NA	Industrial Hazard Only  No cask breach due to design of 10-160B Cask.
1B-2	Diesel fire involving tractor trailer truck (<1475°F; <30 min.)	Human error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on trailer jockey; Unknown ignition source	Potential for smoke to be drawn through WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury; Potential for disruption of processing activities	10-160B Cask design - Meets DOT Type B shipping container certification requirements (withstand fire <1475°F; <30 min.); Emergency Response Procedures; Fire Loading/ Combustible Control Program; Vehicle Maintenance and Inspection Program	NAI	4,4	NA	No cask breach due to design of 10-160B Cask.
1B-3	Diesel fire involving tractor trailer truck followed by an explosion	Human error; Improper or insufficient maintenance; Vehicle impact; Equipment failure; Diesel fuel on trailer jockey; Unknown ignition source	Potential for smoke to be drawn through WHB by ventilation system; Potential loss of exhaust filtration; Potential for worker injury or fatality; Potential for significant disruption of processing activities	Emergency Response Procedures; Fire Loading/ Combustible Control Program; Vehicle Maintenance and Inspection Program; 10-160B Cask design - Meets DOT Type B shipping container certification requirements (withstand fire <1475°F; <30 min.)	NAI	4,4	NA	Worker injury or fatality could result from the explosion (industrial accident).  No cask breach due to design of 10-160B Cask.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
1B-4	Loss of control of truck	Human error; Equipment failure	Potential for equipment damage. Potential for personnel injury. Potential for facility damage.	Preventive Maintenance Program; Procedures and training; Trailer and cask design	NAI	4,4	NA	Industrial Hazard Only
1B-5	RH Bay fire	Diesel fuel fire; Electrical fire; Hydraulic fire	No radiological release; Potential for personnel injury; Potential for facility damage.	Thermal detectors; Building construction Fire Rating Type 2 non-combustible; Cask design; Procedures and training; Fire suppression; Emergency Response; Firewater trenches would collect the diesel fuel and keep the diesel fuel from spreading; Fire Loading/ Combustible Control Program	A-2) Verify the amount of diesel fuel available.	4,4	NA	
1B-6	While moving compressed gas cylinders in RH Bay, cylinder falls - ruptures and impacts cask	Human error; Gas Cylinder failure	Potential for facility damage; Potential for personnel injury/fatality; Potential to breach drum on CH side; Potential for onsite and offsite Consequences; Potential to damage and breach 72B or 10-160B.	Procedures and training; Limited number of cylinders (2); Limited movement of cylinders; Special cart; Cylinder design	A-3) Verify cask design for missile impact.	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
<b>2. Remove the Upper Impact Limiter in RH Bay</b>								
2A-1	Pinch points during removal of ratchet binders		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
2C-1	Impact limiter dropped onto cask	Crane failure; Mechanical failure; Human error; Equipment failure	Potential for damage to impact limiter. Potential for personnel injury. No release. Potential for equipment damage.	Training and Procedures; Crane design; Preventive Maintenance Program on crane; Design of rigging; Frequent crane inspections; Cask design to withstand weight of impact limiter.	NAI	4,4	NA	Industrial Hazard Only
2E-1	Surface contamination on cask and impact limiter - Direct radiological exposure	Seal failure; Human error	Potential for facility worker exposure. Potential for spread of contamination. Potential operational delays.	Training and Procedures; Cask design.	NAI	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - NA	
<b>3. Remove the Cask from the Trailer in RH Bay</b>								
3ABCDEF G-1	Pinch points during removal of cask from the trailer		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
3H-1	Drop cask while lifting from trailer	Crane failure; Mechanical failure; Human error; Equipment failure	Potential for facility damage. Potential for equipment damage. Potential for personnel injury/fatality.	Training and Procedures; Crane design; Preventive Maintenance Program on crane; Design of rigging; Frequent crane inspections; Limited lift height; Limit crane speed; Cask designed to withstand drop up to 40ft.	NAI	4,4	NA	Industrial Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
3H-2	Contaminated water in bottom impact limiter	Human error; Cask contaminated during shipment.	Potential for spread of contamination	Procedures; Impact limiter design (drain in the bottom)	R-1) Survey the bottom of the cask before moving the cask. A-4) Verify drain installed in the impact limiter.	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - NA	Radiological Hazard Only
3I-1	Cask dropped during crane lift to Road Cask Transfer Car (RCTC)	Crane failure; Mechanical failure; Human error; Equipment failure	Potential for facility damage; Potential for equipment damage; Potential for personnel injury/fatality	Training and Procedures; Crane design; Preventive Maintenance Program on crane; Design of rigging; Frequent crane inspections; Cask designed to withstand a drop of up to 40 ft.	NAI	4,4	NA	Industrial Hazard Only
<b>4. Remove Cask Lid in Cask in CUR</b>								
4A-1	Possible spread of contamination while equalizing pressure in Cask	Human error; Equipment failure	Potential for facility worker exposure; (Radiological and hazardous); VOCs; Potential for spread of contamination	Training and Procedures - Pre-operational tests and preventive maintenance on tools; Radiological surveys; HEPA filter tools; WAC - vented drums requirement;	R-2) Verify that HEPA filtration tools have procedures in place.	1,4	Facility Worker - 1,4 Onsite Worker - 1,4 Offsite - NA	No airborne release expected due to HEPA filter on the tools.
4ABC-1	Pinch points while loosening bolts and connection rigging		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
4D-1	Cask falls off of RCTC in RH Bay while lid is loose	Derailment; Vehicle impact; Shield door impact	Potential for loss of production (CH and RH); Potential for breach of drums; Potential for direct radiological exposure to facility worker; Potential for on-site consequence; Potential for off-site consequence; Potential for spread of contamination; Release of hazardous material; Potential for facility and equipment damage	Design of transfer car, shield doors, cask, rails; Emergency Response Procedure; Limited speed on transfer car; DOT Type A Drums; Ventilation system; Training and Procedures; Nuclear coating on floor; ARMs and CAMs.	A-5) Calculation note needed to verify validity of RCTC derailment.	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	
4E-1	Pinch points while closing Cask Unloading Room Shield Door		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
4F-1	Shield plug dropped onto stored WIPP Canister in Hot Cell	Human error; Equipment failure	Potential for breach of canister and drums; Potential for spread of contamination; Offsite and onsite consequences; Potential for release of hazardous waste; Potential to shut down operations	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane design; Frequent crane inspections; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
4G-1	Cask lid dropped onto the cask and drums in CUR	Human error; Equipment failure	Potential for breach of canister and drums; Potential for spread of contamination; Potential for offsite and onsite consequences; Potential for release of hazardous waste; Potential to shut down operations.	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane design; Frequent crane inspections; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
4H-1	Cask lid dropped onto the stored waste in the Hot Cell	Human error; Equipment failure	Potential for breach of canister and drums; Potential for spread of contamination; Potential offsite and onsite consequences; Potential for release of hazardous waste; Potential to shut down operations.	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane design; Frequent crane inspections; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
<b>5. Unload the Cask in the CUR</b>								
5BD-1	Lifting fixture dropped onto the drums in the CUR	Human error; Equipment failure	Potential for breach of drums; Potential for onsite and potential for offsite consequences; Potential for release of radiological and hazardous waste; Potential to shut down operations; Potential for spread of contamination.	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane design; Fixture design; Frequent crane inspections; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
5CE-1	Drum carriage dropped while lifting due to carriage getting caught and over stressing fixture or basket in the CUR	Mechanical/ equipment failure (fixture, sling, etc); Human error	Potential for breach of drums; Potential for spread of contamination; Potential for offsite and onsite consequences; Potential for release of hazardous waste; Potential to shut down operations; Hot Cell and unloading room contaminated.	Fixture design; Drum carriage design; Crane design; Training and Procedures; Ventilation; Emergency Response Procedure; Preventive Maintenance Program on crane; Frequent crane inspections.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
5CE-2	Drum carriage dropped inside the Hot Cell onto stored waste	Human error; Equipment failure	Potential for breach of canister and drums; Potential for spread of contamination; Potential for offsite and onsite consequences; Potential for release of hazardous waste; Potential to shut down operations.	Fixture design; Drum carriage design; Crane design; Training and Procedures; Ventilation; Emergency Response Procedure; Preventive Maintenance Program on crane; Frequent crane inspections.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	
5CE-3	Broken Hot Cell window	Human error (crane, other equipment falling into window); Equipment failure; Nitrogen - over pressurized bladders in window	Potential for loss of shielding to facility worker; Potential for personnel injury	Training and procedures; Preventive maintenance on crane and windows (N <sub>2</sub> bladders in windows have pressure relief valves); Hot Cell leaded glass on outer layer	NAI	2,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	
<b>6. Reinstall Cask Lid in the CUR</b>								
6B-1	Cask lid dropped onto the cask in the CUR	Human error; Equipment failure	Potential for facility damage.	Training and Procedures; Facility design; Preventive Maintenance Program on crane; Crane design; Frequent crane inspections.	NAI	NA	NA	
6B-2	Cask lid dropped onto the stored waste in the Hot Cell	Same as event 4H-1						

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
6B-3	Broken Hot Cell window (internal impact)	Same as event 5CE-3						
6D-1	Shield plug dropped onto stored WIPP Canister in Hot Cell	Same as event 4F-1						
6E-1	Pinch points while opening Cask Unloading Room Shield Door		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
6F-1	Pinch points while moving the RCTC out to the bay to reinstall lid		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
6G-1	Pinch points while connecting rigging		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
6H-1	During cask survey - higher than expected contamination found in RH Bay	Human error; Contamination on inside of cask, lid, and drum carriages (when present)	Potential for facility worker exposure; Potential for loss of production.	Radiological control procedures and training; Radiological monitoring equipment (CAMs); WAC requirements	NAI	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only
6KLMNOP Q-1	Pinch points while reinstalling primary cask lid		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>7. Reinstall the Cask on the Trailer in RH Bay</b>								
7AEFGHIJK L-1	Pinch points while reinstalling the cask on the trailer		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
7BCD-1	Cask dropped while lifting from the RCTC in RH Bay	Same as event 3H-1						Industrial Hazard Only Cask does not contain TRU waste drums.
<b>8. Reinstall the Upper Impact Limiter in RH Bay</b>								
8ABCDE-1	Pinch points while reinstalling the upper impact limiter on the cask		Potential for personnel injury		NAI	1,4	NA	Industrial Hazard Only
<b>9. Move Empty WIPP Canister into Hot Cell and Prepare WIPP Canister</b>								
9-1	Fire in Hot Cell while containing stored waste	Electrical short	Potential for equipment damage; Potential to shut down operations; Potential for drum breach; Potential for onsite and offsite consequences; Damage to Hot Cell.	Fire Loading/ Combustible Control Program; Preventive Maintenance Program on electrical equipment in the immediate area; Hot Cell design; Combustible loading inspections; Procedures & Training; Limited ignition sources	R-3) Verify FHA covers Hot Cell	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
9-2	Fire/Explosion in Hot Cell while containing stored waste	Flammable gas generation in drum and ignites (metal to metal contact causes spark)	Potential for drum breach; Potential for onsite and offsite consequences; Damage to Hot Cell.	WAC - no flammable items in drum; Certificate of Compliance - Limits on gas generation and limited storage; Shield door closed in the CUR and/or Shield plug in Hot Cell is in place.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
9-3	Crane drops off of ceiling supports in Hot Cell	Natural Phenomenon - Seismic and Tornado; External Events - Loss of power; Equipment failure	None - event is prevented by DBE and DBT qualifications of crane	Crane is DBE and DBT qualified	NAI	NA	NA	Event prevented by DBE and DBT qualifications
9-4	Gas cylinder impacts the Hot Cell window (externally - from the Operation Gallery)	Cylinder falls over and becomes a missile	Potential for loss of shielding to worker; Personnel fatality; Potential for facility damage.	Cylinders are chained to cart or wall; Training and procedures; Cylinder and cap design; Hot Cell window design; Preventive Maintenance Program	NAI	4,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	Facility assumes no breach of drums
9-5	Shield plug lift fixture falls over in the Hot Cell	Hit with crane, load on crane impacts window, or equipment.	Potential for broken window (loss of shielding); Potential for onsite/offsite consequences; Potential for facility worker exposure; Potential for Personnel injury	Training and procedures; Ventilation system; Hot Cell leaded glass (outer layer)	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
9-6	External fire to Hot Cell	Hydraulic fuel fire; Fire in the crane maintenance room; Electrical fire	Potential to form toxic gas from neoprene; Industrial hazards from a fire.	Fire brigade - fire protection; Fire Loading/ Combustible Control Program; Training and procedures; Fire detection in Operation Gallery (outside of Hot Cell); Sprinkler system; Hot Cell design; Ventilation.	A-6) Verify gallery combustible loading with facility FPE.	2,4	NA	Industrial Hazard Only  Concrete structure prevents fire from spreading to Hot Cell
9-7	Criticality in the Hot Cell	NA	NA	NA	A-7) Need to update criticality analysis to address this deviation.	NA	NA	HAZOP did not address criticality, but will be addressed in separate evaluation.
9-8	Mishandling of HEPA Filter	Human error	Potential for facility worker exposure	Training and procedures for filter change-out; Personal Protective Equipment; Bag-out process for HEPA filter change-out	NAI	2,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	Covered as part of Maintenance Program
9-9	High Radiation - Direct radiological exposure	Human error; Worker inadvertently enters an area where waste handling is happening. (Transfer Cell or Hot Cell)	Potential for facility worker exposure	Training and procedures; Administrative controls for lock and key; ARM indicators in the Hot Cell and Transfer Cell;	NAI	3,4	Facility Worker - 3,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
9-10	High Radiation - Direct radiological exposure	Human error; Inadvertent entry into CUR while CUR shield valve is open while loading a WIPP Canister into the shuttle car from the Hot Cell	Potential for facility worker exposure (minimal) from Hot Cell	Training and procedures; Facility design (no streaming path).	R-4) Add interlock between CUR shield valve and Hot Cell shield valve	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only  No direct radiation
9-11	High Radiation - Direct radiological exposure	Human error; Inadvertent entry into Facility Cask Loading Room while Transfer Cell shield valve is open while loading a WIPP Canister into the shuttle car.	Potential for facility worker exposure (minimal) from Hot Cell	Training and procedures; Facility design (no streaming path).	R-5) Add interlock between Transfer Cell shield valve and Hot Cell shield valve.	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only  No direct radiation

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
9-12	High Radiation - Direct radiological exposure	Worker inadvertently enters the crane maintenance room while Hot Cell is in operation and opens the shield door	Potential for facility worker exposure (minimal) from Hot Cell	Training and procedures; Facility design (no streaming path).	NAI	NA	NA	<p>Comment: Worker can physically enter Crane Maintenance Room during operation without exposure with Crane Maintenance Room shield door closed, but would typically enter the Crane Maintenance Room during abnormal operations or for routine preventive maintenance (no waste in Hot Cell).</p> <p>No exposure from Hot Cell due to Interlock with crane maintenance shield door on high radiation monitor in Hot Cell.</p>

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
9-13	High Radiation - Direct radiological exposure	Human error; Inadvertently opening CUR shield door with waste inside Hot Cell; Permissive circuit accidentally left in the on position	Potential for facility worker exposure.	Interlock between the grapple and CUR shield door; Permissive circuit to open shield door; Administrative procedures.	R-6) Add interlock between CUR shield door and shield plug	1,4	Facility Worker - 1,4 Onsite Worker - NA Offsite - NA	
9AC-1	Empty WIPP Canister dropped onto stored waste in the Hot Cell	Human error; Equipment; failure; Grapple failure	Potential for breach of canister and drums; Potential for spread of contamination; Potential for offsite and onsite consequences; Potential for release of hazardous waste; Potential for operational down time.	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane/grapple design; Frequent crane inspections; Weight of empty WIPP Canister limits damage to stored waste (1800 lbs.); Inspection that CUR shield door (since shield door can be open if plug is in place); Shield plug in Hot Cell is in place; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	A-8) Verify weight of empty canister.  R-7) Add procedure to verify shield door closed in the CUR during Hot Cell activities.	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Note: Empty WIPP Canisters go through CUR.  Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
<b>10. Unload Carriage Units in Hot Cell</b>								
10A-1	Puncture drum in the Hot Cell with PAR® manipulator	Human error; Equipment failure	Potential for breach of drum; Potential for spread of contamination; Potential for offsite and onsite consequences; Potential for release of hazardous waste; Potential for operational down time.	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on PAR® manipulator equipment and controls; Crane design; Inspection of shield door closed in the CUR; Shield plug in Hot Cell is in place Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 1,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
10B-1	While lifting the drum, drum lid comes off in the Hot Cell	Human error; Equipment failure; Drum lid failure	Potential for drum breach (1 drum); Potential for spread of contamination; Potential for loss of production; Potential for onsite and offsite consequences.	Training and procedure; Preventive Maintenance Program on crane; Drum design; Drum inspection; WAC; Ventilation; Shield door closed in the CUR; Shield plug in Hot Cell is in place.	NAI	3,4	Facility Worker - 1,4 Onsite Worker - 3,4 Offsite - 3,4	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
10BF-1	While lifting the drum, drop drum in the Hot Cell	Human error; Equipment failure (sling)	Potential for onsite and offsite consequences; Potential for spread of contamination; Potential for drum breach (drop on top of other drum).	Training and Procedures; Facility design; Ventilation systems; CAMs; Emergency Response Procedure; Preventive Maintenance Program on crane; Crane design; Frequent crane inspections; Shield door closed in the CUR; Shield plug in Hot Cell is in place; Shield door crane interlocks mitigate direct radiation exposure and/or spread of contamination.	NAI	4,4	Facility Worker - 1,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
10C-1	Higher than expected contamination found on swipe - mishandling by RCT	Human error; Equipment failure (Glovebox leak)	Potential for spread of contamination; Potential for facility worker exposure.	Training and procedure; Glove box design; Inspection of gloves; Preventive Maintenance Program on Glovebox.	NAI	2,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only
10D-1	Radiation exposure during the process of taking swipes or glove box operations	Glovebox interlock failure	Worker exposure to Hot Cell via glovebox.	Interlocks prevent opening both doors (on Glovebox drawer) at the same time; Glovebox design; Training and procedures; Glovebox not in normal streaming path.	NAI	2,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	Radiological Hazard Only
10D-2	Pinch points in glovebox, hands in glovebox, operator opens the gallery side shield plug	Human error; Maintenance activity	Potential for personnel injury.	Pressure pad (Hot Cell/Glovebox controls) interlock with shield plug; Training and procedures; Preventive Maintenance Program on Glovebox; Configuration of equipment controls.	NAI	1,4	NA	Industrial Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
<b>11. Prepare WIPP Canister for Disposal</b>								
11D-1	Fire in the Hot Cell	Heat generated by welding causes ignition of combustibles inside canister	Potential for onsite/offsite consequences; Potential for spread of contamination; Potential for facility damage; Potential for equipment damage.	Robotic welder design; WAC (no flammable material); (i.e.: two mechanical failures to cause accident); Storage limits on waste (LFL); Lid design; WIPP Canister design; Training and procedures; Ventilation; Fire Loading/ Combustible Control Program; Thermal detector; Shield door closed in the CUR; Shield plug in Hot Cell is in place.	NAI	4,4	Facility Worker - 2,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
11D-2	Explosion in the Hot Cell	Ignition of flammable gases in canister head space during welding activities	Potential for drum breach; Potential for damage to Hot Cell; Potential for loss of shielding to facility worker; Potential for onsite/offsite consequences; Potential for worker fatality; Potential for spread of contamination.	Limited storage time in the Hot Cell; Training and Procedures; Canister lid design; Preventive Maintenance Program on welder; WAC (no flammable material); Vented drums and canister; Ventilation; Shield door closed in the CUR; Shield plug in Hot Cell is in place.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
11D-3	Halogenated hydrocarbons accumulate in WIPP Canister head space and welding activity produces phosgene gas (toxic) in the Hot Cell	Chemical reaction to ultraviolet light	Potential onsite exposure to toxic gas.	Ventilation system dilutes; Training and procedures; Canister design; WAC.	A-9) Verify requirements about allowable levels of halogenated hydrocarbons in the drum.  A-10) Verify the hazardous chemical inventory in the waste.	3,4	NA	Ventilation flow rate will dilute the gas.  Requires further Accident Analysis
11F-1	Loaded WIPP Canister dropped in the Hot Cell	Canister lid failure; Grapple failure; Welding failure; Human error; Shear crane cables	Potential for breach of canister; Potential for breach of drums; Potential for facility damage; Potential for onsite/offsite consequences; Potential for spread of contamination; Potential for facility worker exposure	Grapple design; Preventive Maintenance Program on crane; Training and procedures (welding); Canister design; Lid design; Robotic welder design; Shield door closed in the CUR; Shield plug in Hot Cell is in place.	NAI	4,4	Facility Worker - 1,4  Onsite Worker - 4,4  Offsite - 4,4	Radiological Hazard Only
<b>12. WIPP Canister Transfer to Shuttle Car in Transfer Cell</b>								
12D-1	Loaded WIPP Canister dropped in the Hot Cell	Same as event 11F-1			NAI			

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
12E-1	Drop the loaded WIPP Canister into the Transfer Cell	Equipment failure; Human error; Lid failure; Welding failure	Potential for breach of canister and drums; Potential to spread contamination; Potential for offsite/onsite consequences; Potential for facility damage; Potential for shuttle car damage; Potential to shut down RH operations.	Guide tubes; Training and Procedures; Preventive Maintenance Program on crane; Design of shuttle car (designed to shear away and absorb impact); Impact limiters on the floor; Design of lid.	NAI	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	Radiological Hazard Only
12E-2	Hot Cell shield valve inadvertently closes on WIPP Canister and shears the canister	Mechanical-electrical failure or control system failure	Potential for breach of drums; Potential to spread contamination; Potential for offsite/onsite consequences; Potential for facility damage; Potential to shut down RH operations.	Crane and Hot Cell shield valve interlock; Torque limiter on shield valve motor; Preventive Maintenance Program on shield valve and controls; Design of canister.	A-11) Check design of WIPP canister.	4,4	Facility Worker - 4,4  Onsite Worker - 4,4  Offsite - 4,4	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
12E-3	Inadvertent movement of crane (east/west) while lowering WIPP Canister into Transfer Cell	Mechanical-electrical failure or control system failure; Human error	Potential for breach of drums; Potential to spread contamination; Potential for offsite/onsite consequences; Potential for facility damage; Potential for shuttle car damage; Potential to shut down RH operations.	Crane and shield valve interlock; Torque limiter on shield valve motor; Preventive Maintenance Program on crane; Design of canister; Emergency stop in crane.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only
12E-4	Inadvertent movement of the shuttle car with the WIPP Canister partially lowered	Mechanical-electrical failure or control system failure (shuttle car failure); Human error; Interlock failure (shuttle car is interlocked with shield valve).	Potential for breach of drums; Potential to spread contamination; Potential for offsite/onsite consequences; Potential for facility damage; Potential for shuttle car damage; Potential to shut down RH operations.	Variable speed drive motor controller (limits motor current and stops motor when shuttle is obstructed); Preventive Maintenance Program on shield valve/shuttle car interlock; Canister design; Drive train on shuttle car - belts will slip; Interlock between shuttle car and shield valve.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	Radiological Hazard Only

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>13. Move WIPP Canister into Position in the Transfer Cell</b>								
13ABCD-1	WIPP Canister moved into position in the Transfer Cell	Same as events 5-3 through 5-6 - 6-1, 6-2, and 6-5 in DOE/WIPP-00-2305						
<b>14. Load WIPP Canister into Facility Cask in the Transfer Cell</b>								
14ACDEFG HI-1	Load WIPP Canister into facility cask in Transfer Cell	Same as events 7-1 through 7-13 in DOE/WIPP-00-2305			NAI			
14B-1	Robotic arm damages WIPP Canister during contamination survey	Equipment failure (Robotic control failure)	Potential for breach of drums; Potential to spread contamination; Potential for offsite/onsite consequences; Potential for facility damage; Potential for shuttle car damage; Potential to shut down RH operations; Potential damage to Robotic arm.	Robot design (device is not strong enough to penetrate the canister); Collision detector; Force limiter on swipe arm.	NAI	4,4	Facility Worker - 4,4 Onsite Worker - 4,4 Offsite - 4,4	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>15. Facility Cask Loaded onto Hoist</b>								
15ABC-1	Facility cask to Hoist	Same as events 8-1 through 8-7 in DOE/WIPP-00-2305			NAI			
<b>16. Facility Cask Transfer to Disposal Room</b>								
16ABCD-1	Facility cask to H.E.R.E.	Same as events 9-1 through 9-8 in DOE/WIPP-00-2305			NAI			
<b>17. Cask Emplacement in Bore Hole</b>								
17ABCD-1	H.E.R.E. to Emplacement	Same as events 10-1 through 10-7 in DOE/WIPP-00-2305			NAI			
<b>18. CH/RH Interface (covered by DOE/WIPP-00-2305)</b>								

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>19. Storage Mode (covered by DOE/WIPP-00-2305)</b>								
<b>20. Natural Events</b>								
20-1	Loss of confinement in RH Bay due to seismic event (lid is loose on cask)	Seismic event	Potential for major disruption of facility operations; Potential damage to cask and/or canister; Potential breach of drums due to loose cask lid in RH Bay; Potential for loss of site utilities; Potential to release radioactive material; Potential for fire; Potential for explosion; Potential for worker injury or fatality; Potential for breach of drums; Potential for onsite/offsite consequences; Potential for facility worker exposure.	Waste Handling Building is DBE qualified; Crane is DBE qualified; Emergency Response Plan; Recovery Plan; 10-160B Cask design - meets DOT Type B shipping container certification requirements; HVAC system shutdown switch; Hot Cell is DBE qualified.	A-12) Verify the Mezzanine design is DBE qualified.	4,3	Facility Worker - 4,3 Onsite Worker - 4,3 Offsite - 4,3	Worker injury or fatality could occur as the result of the earthquake alone. Radiological impact would likely be extensive.
20-2	Full facility fire	Seismic	Potential for breach of drums; Potential for onsite/offsite consequences; Potential for facility worker exposure.	Waste Handling Building DBE qualified; Crane is DBE qualified; PAR® is DBE qualified; Hot Cell is DBE qualified.	NAI	4,3	Facility Worker - 4,3 Onsite Worker - 4,3 Offsite - 4,3	

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
20-3	Loss of confinement due to Tornado.	Tornado	Potential for breach of drums due to loose cask lid in RH Bay ; Potential for onsite/offsite consequences; Potential for facility worker exposure; Potential for disruption of processing operations; Potential to lose site utilities; Potential for worker injury or fatality; Potential for fire; Potential for explosion; Potential for breach of drums in Hot Cell.	Waste Handling Building DBE and DBT qualified; Emergency Response Procedures; Recovery Plan; Weather monitored by CMR (Central Monitoring Room); 10-160B Cask design - meets DOT Type B shipping container certification requirements; Hot Cell is DBT qualified.	A-13) Verify shield door is DBT qualified.	4,2	Facility Worker - 4,2 Onsite Worker - 4,2 Offsite - 4,2	Worker injury or fatality could occur as the result of the tornado.
20-4	Range Fire	Lightning; unknown ignition source Gas pipeline explosion	Potential to disrupt site operations; Potential for smoke to enter the mine shaft; Potential for underground evacuation; Potential for smoke to enter facility buildings; Potential for facility damage	Emergency Response Procedures; Fire break installed; Fire fighting capability; Emergency response team; Fire fighting training; 24 hour fire brigade	NAI	2,4	NA	Industrial accident only. Potential for a range fire having a direct impact on the WHB such that a radiological release would occur is minimal

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
20-5	Cold Weather Natural Ventilation Pressure results in changes to air balance (Underground ventilation system)	Cold weather caused Natural Ventilation Pressure (NVP)	Potential to disrupt waste handling operations; Potential to, in the event of an accident involving release of radiological material, spread airborne contamination to the environment; Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt; Potential for waste shaft hoist to fail; Potential for worker injury	Operator training and qualification; Waste shaft hoist system design; Operating procedures; Air balance and flow tests; Shaft pressure monitoring; Alarms to indicate adverse air pressure conditions; WIPP ventilation simulator used for guidance; Underground ventilation remote monitoring control system (monitors air flows and d/p's and enable CMR operator to adjust vortex to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure); Isolation of mine splits; Backup power available to operate fans for flow through the panel area	NAI	3,4	NA	There would be no radiological hazard as the result of the cold weather NVP event unless there was already contamination present in the mine. Injury to worker related to industrial mining safety.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
20-6	Hot Weather Natural Ventilation Pressure results in changes to air balance (Underground ventilation system)	Hot weather caused Natural Ventilation Pressure (NVP)	Potential to disrupt waste handling operations; Potential to, in the event of an accident involving release of radiological material, spread airborne contamination to the environment; Potential to cause deterioration of braking and electronic systems for the waste shaft hoist during prolonged exposure to salt Potential for waste shaft hoist to fail; Potential for worker injury	Operator training and qualification; Waste shaft hoist system design; Preventative maintenance procedures; Air balance and flow tests; Monitoring at bulkhead 309; Bulkhead 309 design to pressurize the chamber between the walls of the 309 bulkhead using fans; Procedures to maintain differential pressures in the mine; WIPP ventilation simulator used for guidance; Underground ventilation remote monitoring control system (monitors air flows and d/p's and enables CMR operator to adjust vortex to control flow) Mine weather stations to monitor natural ventilation pressure(temp, relative humidity and barometric pressure); Isolation of mine splits; Backup power available to operate fans for flow through the panel area; Alarms to indicate adverse air pressure conditions	NAI	3,4	NA	There would be no radiological hazard as the result of the hot weather NVP event unless there was already contamination present in the mine. Injury to worker related to industrial mining safety.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
<b>21. Common Events</b>								
21-1	Loss of Facility ventilation	Human error- Improper bulkhead alignment Equipment failure -Failure of exhaust fans; Loss of electrical power; Loss of compressed air	Potential to shutdown operations	Worker training; Ventilation system operating procedures; Preventive Maintenance Program for ventilation system equipment; Redundant Exhaust fans; Evacuation plan; Backup diesel generators; Redundant air compressors	NAI	NA	NA	No release of radiological materials
21-2	Loss of power	NPH - Earthquake, tornado, lightning, high winds, etc.; Vehicle impact; Power from commercial supplier is lost	Potential loss of filtered ventilation; Potential loss of hoist	Backup diesel generators; Redundant power feeds; Response procedures; Worker training; Fail-safe design of cranes, hoist.	NAI	NA	NA	No release of radiological materials

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
21-3	Loss of Fire Protection (includes detection and suppression)	NPH; Loss of 180,000 gallon fire water storage tanks	Potential inability to detect and suppress fires	Design and construction of fire suppression system; Two on-site fire water storage tanks containing 180,000 gallons (One storage tank capacity sufficient for DBF); Two fire pumps, one electrical and one diesel, available; On-site fire truck and fire fighting equipment All fire related systems, training, inspection, and testing are in accordance to NFPA (National Fire Protection Association) and NEC regulations Inspections and functional tests of system performed on a periodic basis 24 hour battery backup for fire detection system available in WHB; 24 hour fire brigade	NAI	NA	NA	Ranking would be significant only if there were a fire event and the detection and suppression systems were inoperative. Otherwise, loss of the detection and suppression systems has no impact.
21-4	Loss of Plant Air	NPH; Loss of power; Mechanical failure	Unable to open/close CUR shield door; Facility down time.	Interlock between CUR shield door and grapple prevents movement of waste while shield door is open.	NAI	NA	NA	Shield door fails as is during a loss of plant air.  If shield door is open upon loss of plant air, waste can not be moved with the grapple due to the interlock. No hazardous condition exists, therefore, on a loss of plant air.

Table 2- 10-160B HAZOP Table

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons.,Freq)	Comments
21-5	Loss of Facility heating causes loss of shielding via Hot Cell windows	Loss of power; Mechanical failure	Potential for facility worker exposure.	Preventive Maintenance Program on Facility heating; Redundant ventilation trains (design); 10-stage sequence heater; Emergency management loss of power; Drums on floor stacked 1-high are below streaming path; Training and procedures.	NAI	2,4	Facility Worker - 2,4 Onsite Worker - NA Offsite - NA	Note: Below 50 degrees for months (extended period of time). Loss of cooling is not a problem - temperature will not go below 50 degrees due to heat sink of the building.
<b>22. External Events</b>								
22-1	Aircraft Crashes Into WHB	Personnel error; Equipment failure	Potential for major damage to WHB; Potential for fire; Potential for worker injury or fatality; Potential for major release of radioactive material; Potential for considerable radiological exposure to personnel	Physical location of site is remote; Air space above facility is not part of normal flight patterns; Physical size of WHB	NAI	4,1	Facility Worker - 4,1 Onsite Worker - 4,1 Offsite - 4,1	This event would have major radiological and non-radiological impact. However, the event is beyond extremely unlikely and does not require accident analysis. Worker injury or fatality could result from this industrial accident

Study Node Event No.	Deviation	Causes	Consequences	Existing Safeguards	Actions	Total Rank (Cons., Freq)	Radiological Rank (Cons., Freq)	Comments
22-2	Gas Pipeline Explosion	Loss of pipe integrity, spark Natural gas explosion; Range Fire	Potential for fire; Potential for off- site personnel injury or fatality; Potential environmental concern; Potential to stop site operations	WHB is located one mile from nearest pipeline. Damage radius from recent explosions is a few hundred feet	NAI	2,4	NA	Risk associated with this event is similar to that of the general public, furthermore the nearest gas pipeline is approximately one (1) mile from site boundary.
22-3	Vehicle crash from CH to the RH Bay (Forklift crashes through the roll up door)	Human error; Mechanical failure	Potential to lose DP between RH Bay and CH Bay; Potential for facility damage; Potential for personnel injury (see WIPP SAR).	Training and procedures; Preventive Maintenance Program on CH/RH vehicles; Design of forklift (dead man switch); Design of lid; Design of cask.	NAI	4,4	NA	Industrial Hazard Only

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