SAFETY ANALYSIS OF ACCIDENTS DURINGBELOW-GROUND VAULT DISPOSAL OPERATIONS

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ABSTRACT

A safety assessment of accidents and unusual operational conditions is an essential component of a Safety Analysis Report for a Low-Level Radioactive Waste Disposal Facility. A safety analysis of accidents and unusual operational conditions was performed for a below-ground vault disposal facility as part of the Prototype Licensing Application Project conducted by Rogers and Associates Engineering Corporation for the Department of Energy.

A list of accidents and abnormal events was developed from waste handling operations. Bounding accident scenarios were identified from general considerations and relative scoping analyses. Doses were then calculated for workers and offsite individuals of the site boundary. Onsite doses are less than 100 mrem, and all doses to offsite individuals are much less than 1 mrem.

INTRODUCTION

A safety assessment of accidents and unusual operational conditions is an essential component of a Safety Analysis Report for a Low-Level Radioactive Waste (LLW) Disposal Facility. A safety analysis of accidents and unusual operational conditions was performed for a below-ground vault (BGV) LLW disposal facility as part of the Prototype Licensing Application Project conducted by Rogers and Associates Engineering Corporation for the Department of Energy through EG&G Idaho(1).

SELECTION OF LIMITING ACCIDENTS

A comprehensive list of accidents and unusual operational conditions that could occur during the operating and closure periods of the below-ground vault LLW disposal facility was initially developed. To identify these accidents, detailed descriptions of operations relating to the receipt, inspection, and disposal of LLW at the facility and of operations required to close the facility were reviewed. These operations and the physical characteristics of the facility were analyzed to define accidents or unusual events that could potentially result in significant exposures to workers or the general public. To ensure that accident scenarios are realistic in terms of facility design and operating characteristics, the following criteria were applied:

- Accident scenarios were rejected if regulatory requirements preclude their occurrence or otherwise limit the release of radioactivity.
- Accident scenarios were rejected if proposed conditions of waste acceptance and facility design and operations preclude their occurrence or otherwise limit the release of radioactivity.

Extremely low probability accidents were rejected from consideration. Although no quantitative event probability analyses were performed, best engineering judgement was used in rejecting extremely low probability events. The set of accidents (whose consequences generally bound the consequences of all accidents listed) selected for analysis are reasonably conservative.

Potential accidents could involve the rupture of a waste container and subsequent release of a portion of the radioactivity; container rupture could be caused by an explosion or by the container being punctured, dropped, or dropped onto. A fire on the site could consume the combustible contents of a waste package and release a portion of the contained radioactivity to the atmosphere. Natural events such as floods or tornadoes could disperse radioactivity to offsite locations where the public could be exposed. In addition, some occurrences can be postulated that would result in exposure of onsite workers but no exposure of the general public, such as cleanup activities, spills contained within buildings, and direct gamma radiation incidents.

The types and magnitudes of accidents potentially occurring during the operational phase of the disposal facility are generally similar to those that might occur during transportation of the LLW to the disposal site. Most accidents would involve dispersal of a small fraction of the radioactivity contained in one or a small number of waste containers. Waste acceptance criteria and operating procedures at the disposal facility would limit the magnitudes of any releases. Except for waste which is assumed to arrive at the disposal facility in polyethylene High Integrity Containers (HICs), all waste will be packaged in steel drums, boxes, or liners. Wet wastes are assumed to be immobilized in cement. Waste forms for Class B/C wastes must satisfy the stability requirements of 10 CFR 61. This will ensure that these wastes are in a relatively non-dispersible form.

The accidents, listed in Table I, can be grouped in terms of initiating events or exposure mechanisms into several groups. There are:

- Unusual operational conditions that require cleanup by site workers but do not result in exposure of the general public.
- Offsite releases of radioactivity caused by fires.
- Waste container ruptures caused by puncturing, dropping, dropping onto, or explosions.
- Offsite releases of radioactivity caused by natural events.

For each category of accident, bounding accidents were determined. Bounding accidents are judged to have the greatest potential for public or worker exposure to radioactivity. This judgement was made on the basis of the characteristics of the radioactive waste in the

TABLE I

Accidents and Unusual Operational Conditions for Below-Ground Vault Disposal Facility

Scenario Number	Accident or Unusual Operational Condition	Reference Waste Container	Exposure Pathways: Onsite Workers	Exposure Pathways: Offsite Individuals
Unusual Operational Conditions				
1	Shipment of defective drums is received at waste receiving and storage building, resulting in contamination release to the building.	Drum of typical Class A dry active waste reading 1 R/hr	Direct Radiation Air	---
2*	Cask used to transport waste is opened and the inside liner is found to be ruptured. The liner and the inside of the cask are contaminated with radioactivity.	Large liner of typical Class A dry active waste reading 10 R/hr at contact.	Direct Radiation Air	---
Fire				
3*	Fire occurs during repackaging operations in the decon room of the waste receiving and storage building and spreads to the HEPA filters.	Box of typical Class A dry active waste reading 1 R/hr at contact.	Air Direct Radiation	Air
4	Combustible material mistakenly left in the storage room of the waste receiving and storage building catches fire. Pallets burn and waste containers topple over and break open. Fire spreads to HEPA filters.	Drum of average Class A dry active waste.	Air Direct Radiation	Air
5	Fire occurs in partly filled disposal unit.	Drum of average Class A dry active waste.	Air Direct Radiation	Air

* The asterisk denotes the bounding accident for each accident category.

TABLE I

(Continued)

Scenario Number	Accident or Unusual Operational Condition	Reference Waste Container	Exposure Pathways: Onsite Workers	Exposure Pathways: Offsite Individuals
Container Rupture				
6*	Forklift accident during unloading/loading operations in the waste receiving and storage building results in container rupture and the release of radioactivity to the building.	Drum of typical Class A dry active waste reading 1 R/hr at contact.	Direct Radiation Air	---
7	A hydrogen reaction in a waste container results in an explosive release of radioactivity from the container.	Drum of average Class A dry active waste.	Air Direct Radiation	Air
8*	A disgruntled employee attaches an explosive device to a vehicle used to transport waste containers to the disposal area or to a crane used to unload the containers. When the device detonates, one or more containers ruptures, releasing radioactivity to the atmosphere and the ground	Box of typical Class A dry active waste reading 1 R/hr at contact.	Air Direct Radiation	Air Surface Water
Container Dropped or Dropped Onto				
9	Waste containers fall from the flatbed truck being used to transport the containers from the waste receiving and storage building to the disposal area. One or more containers ruptures, releasing radioactivity to the atmosphere and the ground.	Drum or box of typical Class A dry active waste reading 1 R/hr at contact.	Direct Radiation Air	Air Surface Water

* The asterisk denotes the bounding accident for each accident category.

TABLE I

(Continued)

Scenario Number	Accident or Unusual Operational Condition	Reference Waste Container	Exposure Pathways	
			Onsite Workers	Offsite Individuals
10	A concrete cover block for a B/C disposal unit drops into the partly filled cell and crushes several waste containers, resulting in a release of radioactivity.	Cell contains drums and liners of average Class B/C waste.	Direct Radiation Air	---
11	The crane being used to unload waste containers from a flatbed truck drops its load onto the ground or into the partly filled disposal cell. Container rupture occurs and radioactivity is released to the atmosphere and the ground.	Liner of B-IXRESIN waste reading > 1 R/hr at contact. Cell contains liners of high-gamma Class A waste. (Assume the rupture of a HIC containing P-FCARTRG waste.)	Direct Radiation Air	Air
Crane Malfunction				
12*	The crane being used to unload waste containers malfunctions, and a container remains suspended in the air until it can be released or transferred to another crane.	Item of L-NRFCOMP Class B/C waste reading 440 R/hr at contact.	Direct Radiation	---
Natural Event				
13*	A load of waste containers is stranded in the disposal are without cover and without being placed in a disposal cell. A tornado occurs which results in container rupture and the transport of radioactivity from the disposal site.	Box of typical Class A dry active waste reading 1 R/hr at contact.	Direct Radiation Air	Air

* The asterisk denotes the bounding accident for each accident category.

TABLE I

(Continued)

Scenario Number	Accident or Unusual Operational Condition	Reference Waste Container	Exposure Pathways: Onsite Workers	Exposure Pathways: Offsite Individuals
14	Demolition of a contaminated structures (the waste receiving and storage building), coupled with a high wind or tornado, results in the airborne release of radioactivity.	Nuclide proportions like unsolidified waste. Contamination levels at NRC release limits.	Direct Radiation Air	Air
15	Demolition of a contaminated structures (the waste receiving and storage building) coupled with a heavy rain or snowmelt and surface runoff, results in the surface release of radioactivity.	Nuclide proportions like unsolidified waste. Contamination levels at NRC release limits.	Direct Radiation	Surface Water

* The asterisk denotes the bounding accident for each accident category.

containers involved in accidents, mechanisms for release and dispersal of the radioactivity, the potential magnitude of exposures, and the comparative likelihood of occurrence. In Table I, bounding accidents are indicated by an asterisk (*).

DESCRIPTION OF ACCIDENTS

Brief descriptions of the limiting accident scenarios are given in the following paragraphs.

Scenario 2: Contaminated Cask and Liner

Radioactive waste arriving in a shielded shipping cask is taken to the inspection bay of the Receiving and Storage Building where the cask lid is removed, an inspection is made of the liner, and the lid is replaced. In this scenario, damage to the liner is detected by contamination found on the wipes made of the liner surface. The liner contains unsolidified Class A dry active waste and has a surface dose reading of 10 R/hr. The cask is moved to the decontamination/repacking room truck bay. The remove overhead crane is used to remove the liner and overpack it in a larger liner. The remote manipulation and hot cell facilities are used as required.

Any dispersed radioactivity is contained in the Receiving and Storage Building, and this scenario does not result in any exposure to offsite persons. Onsite workers receive small additional exposures during operations to overpack the liner, decontaminate the cask, and clean up any spillage.

Scenario 3: Fire in Decontamination Room

In this accident scenario it is postulated that a fire starts in an open container of combustible waste in the decontamination room of the waste Receiving and Storage Building. The decontamination room has its own ventilation system and air is normally released from the room to the outside environment through HEPA filters. It is assumed for this accident that the fire spreads to the filters and destroys them, permitting a release of radioactivity from the building.

To provide a significant, realistic source of combustible materials, the reference container is postulated to be a box containing Class A dry active waste reading 1 R/hr at contact. Conservatively, the entire contents of the box are considered to be combustible and to be burned. Since failure of the HEPA filters permits the release of airborne contaminants, offsite individuals breathing the contaminated air could receive an inhalation dose. Onsite workers are exposed to direct radiation and possible inhalation doses while fighting the fire which is assumed not to be contained until the entire contents of the box have been burned. It is expected that ash dispersal and deposition through the decontamination/repackaging room will need to be cleaned up.

Due to the greater volume of waste in a single container, the greater potential for ignition of an open container, and the greater level of personnel activity proximity to the exposed waste, it is considered that Scenario 3 represents a more probable and conservative accident to analyze than Scenarios 4 or 5.

The personnel within 6 ft (1.8 m) of the open box when it catches fire are two workers who were preparing to engage in decontamination/repackaging procedures. Within 30 seconds of the beginning of combustion they have left the immediate area of the box to summon firefighting assistance and obtain a fire extinguisher. Although opening a waste box in the decontamination room is an operation requiring respiratory protection, to be conservative it will be assumed that each worker breaths two breaths from the smoke cloud before putting his respiratory protection into place as he leaves the area. All other workers in the building put on respiratory protection and evacuate before the smoke cloud approaches. All fire fighting personnel are equipped with full respiratory protection and no additional inhalation exposures occur.

Of the suspended particulates released by the fire, half escapes through the building exhaust, and half is redeposited in the building. An additional ten percent of the box contents is assumed to be dispersed about the decontamination/repackaging room as ash. Decontamination of the building is considered to take four workers two weeks, including repackaging the box and ash. This work is conducted with full respiratory protection and no additional indoor inhalation exposures occur.

Scenario 6: Forklift Accident

Forklifts are used at the Receiving and Storage Building to transfer drums and boxes of unshielded radioactive waste from closed vans to flatbed trucks used for onsite transport of the waste to the disposal area. A forklift accident that may rupture waste containers during unloading/loading operations could result when a:

- Forklift drops a container (or a pallet of containers)
- Forklift tips over while transporting a container
- Forklift runs into a container
- Forklift fork punctures a container.

The damage to a container and the subsequent release of radioactivity will be limited by the fact that all waste arriving at the disposal facility is packaged in steel containers (steel drums, boxes, or liners) that are more difficult to rupture than wooden boxes. Any release of contamination from a forklift accident will be confined inside the waste Receiving and Storage Building.

To provide a dispersible source of unshielded waste, the reference container for a forklift accident is assumed to be a drum of Class A dry active waste with a surface dose rate of 1 R/hr. Since there would be no release of radioactivity from the confines of the building, there would not be any exposure of offsite individuals. Onsite workers would receive small additional exposures while cleaning up the contamination inside the building and repackaging the waste.

It is assumed that the entire contents of one drum of dry active waste is dumped to the floor of the inspection room as a result of the forklift accident. The personnel in the immediate area are the forklift operator, an HP technician, and a QA technician who are doing the receiving and inspection.

All cleanup activities are conducted with respirators on. The cleanup consists of shoveling the waste into a container, vacuuming and mopping. These activities contribute external gamma exposures. In the decontamination room remote handling is used for repacking and overpacking the waste and no additional exposures occur.

Scenario 8: Detonation of Intentionally Placed Explosive Device

It is postulated that a disgruntled former employee gains access to the site, attaches an explosive device to a truck used to transport waste containers to the disposal area. The explosive device detonates and a container of radioactive waste is ruptured. Radioactivity is released to the air and the ground surface.

The disposal area is contoured and provided with an engineered drainage system that prevents surface water runoff to nearby streams. To allow an offsite surface water pathway for migration of the radioactivity that is on the ground following this accident, the explosion is postulated to occur near the security gate to the disposal area. A heavy rainstorm occurs before cleanup of the ground contamination can be accomplished.

To achieve the maximum release of radioactivity from this accident an unshielded container of easily dispersible waste is assumed. The postulated waste source is a box of Class A dry active waste reading 1 R/hr at contact.

Among the outdoor container rupture accidents this scenario has the greatest potential for waste release. Exposure pathways for offsite individuals include the air pathway (through inhalation of contaminated dust) and the surface water pathway. Exposure pathways for onsite workers include direct exposure to gamma radiation and the inhalation pathway.

The explosion is assumed to result in the scattering of the entire waste contents of the box of dry active waste over a 30 ft (9 m) radius. The explosion releases 5 percent of the waste volume as suspended particulates.

The truck driver is the only person in proximity at the time of the explosion. He puts on a respirator after taking two breaths in the contaminated cloud. Other onsite workers wear respiratory protection as they respond to the accident.

Seventy-five percent of the initial contents of the box is assumed to remain on the ground following the explosion and rain. This material is cleaned up using a frontend loader and workers with shovels. Respiratory protection is required during the cleanup and the only additional exposures are to external gamma radiation. It is assumed that the frontend loader, and two workers assisted by an HP technician require four hours to cleanup the spill.

Scenario 12: Container Remains Suspended from Crane

The malfunctioning of a crane used to unload a waste container from a flatbed truck and place it in a disposal cell could result in the container remaining suspended in the air. Workers involved in the transfer could experience large incremental direct radiation doses depending on the radioactivity in the waste package and on the difficulty and time required to correct the crane malfunction. The potential exists for offsite individuals to be exposed to exposure rates elevated slightly above background.

For this accident, it is assumed that a crane malfunction occurs while transferring a waste package with a surface dose reading of 440 R/hr. An analysis will be made of this scenario as a bounding example.

Scenario 13: Waste Container Unprotected During Storm

For this scenario it is postulated that boxes or drums of Class A dry active waste reading 1 R/hr at contact are in the disposal are when a tornado occurs. The tornado causes one of the boxes to rupture and radioactivity to be transported from the disposal site.

As a result of this accident, offsite individuals can be exposed by breathing contaminated air. Onsite workers are exposed to direct gamma radiation and to contaminated air during cleanup operations at the site.

Scenario 13 has the greatest potential for radioactivity release of the three natural event accidents. Due to the high wind speeds and the fact that most people will take cover when a tornado approaches, however, inhalation doses are expected to be low. This accident has characteristics similar to Scenario 8 (explosive device) and is considered to be bounded by that accident.

CALCULATED DOSES

Onsite inhalation doses are calculated from the airborne concentration is either estimated from airborne puff considerations or calculated with a Gaussian Puff model, from an assumed one liter of air intake per breath, and from standard inhalation dose conversion factors.

External gamma exposure from waste packages are based on the calculated exposure rates using ISOSHIELD(2), and scaling of those exposure rates for dispersed or spilled wastes. The method used for estimating the person-R accumulated for a particular operation is based on the number of workers and their times at various distances from particular sources. The external radiation exposures are based on conservative cleanup scenarios including surveys of the extent of contamination, cleanup activities, and repackaging of the waste.

Remote handling methods are assumed where they are in general use for similar non-accident situations.

For each of the bounding accident scenarios, the offsite and onsite dose estimates are given in Table II.

Onsite doses are less than 250 mrem and are significantly less than worker limits. The forklift accident causes the highest inhalation dose to workers and the crane malfunction gives the highest external gamma dose to workers. All doses to offsite individuals are much less than 1 mrem.

REFERENCES

1. "Prototype License Application: Safety Analysis Report, Below-Ground Vault," U.S. Department of Energy report DOE/LLW-72T, October 1988.
2. R.L. ENGLE et al., "ISOSHLD, A Computer Code for General Purpose Shielding Analysis," Atomic Energy Commission report BNWL-2316, June 1966.

TABLE II

Estimated Doses From the Bounding Accident Scenarios

Scenario Number	Onsite Inhalation Dose (person-mrem)	Onsite Gamma Doses (person-mrem)	Fence Line Offsite Inhalation Dose (mrem)	Individual Offsite Surface Water Doses (mrem)
2	4.5	5.4	---	---
3	2.8	14	0.036	---
6	22	27	---	---
8	2.3	52	0.14	9.6×10^{-7}
12	---	212	---	---