# 9. DESIGN FOR CARETAKER, RETRIEVAL, PERFORMANCE

## 9.1 CARETAKER OPERATIONS

The caretaker phase of the repository operation will begin when the last waste package is emplaced and will continue until activities begin to decommission and close the facility. Primary activities to be carried out during the caretaker phase are monitoring and maintenance of the facility and execution of the performance confirmation program. The length of the caretaker period is set by the lengths of the retrievability period and the waste emplacement schedule, as discussed below.

### 9.1.1 Previous Work

Little design activity has been directed specifically toward the caretaker phase since the beginning of repository advanced conceptual design in 1993. There appear to be no major technical issues associated with execution of the caretaker period, with the possible exception of the issue of the longevity of the facility itself. The duration of the caretaker period has increased from 26 years to 76 years as a result of a DOE decision documented in the *Civilian Radioactive Waste Management Program Plan* (DOE 1994b). This extended period will increase the likelihood of age-related failures of the tunnels and installed components, and will result in higher maintenance-related costs in the latter years of the caretaker phase.

### 9.1.2 Design Inputs

All text in this subsection is excerpted directly from the *Repository Design Requirements Document* (RDRD) (YMP 1994a), the reference source for repository requirements. Upper-level requirements from within the program (e.g., MGDSRD and CRD) and outside the program (such as 10 CFR 60 requirements) are included in the RDRD (YMP 1994a). The specific requirements from the document quoted below are considered applicable to aspects of the caretaker function. Other requirements from the RDRD (YMP 1994a), which may apply in a more general way, are not included here.

> 3.2.1.3 CARETAKER MODE REQUIREMENTS
>
> When the repository has reached its legislated or physical capacity for waste disposal, it will be in the caretaker mode. The option to retrieve any and all emplaced waste will be preserved from the time of emplacement for up to 50 years. Performance confirmation will continue during this mode.
>
> The GROA [geologic repository operations area] shall be designed so that until permanent closure has been completed, radiation exposures, radiation levels, and releases of radioactive materials to unrestricted areas will at all times be maintained within the limits specified in 10 CFR 20 and applicable environmental standards for radioactivity established by the EPA [U.S. Environmental Protection Agency] as listed in Section 3.2.2.

NOTE: As discussed above, the period of retrievability has been extended to 100 years. Therefore, the length of the caretaker period has also been extended. Taken in conjunction with a 24-year waste receipt and emplacement schedule, this 100-year retrieval period sets the duration of the caretaker phase at 76 years.

### 9.1.3 General Description

As previously noted, the caretaker phase begins upon completion of waste emplacement operations. During the caretaker period, the surface waste handling facility will be in a "cold shutdown" or "mothballed" condition. The only surface facilities in continuous operation during the caretaker phase will be those supporting the ongoing operation of the subsurface facility.

Two primary functions will be ongoing during the caretaker phase: maintenance of the facility to provide access and preserve the retrievability option, and execution of the performance confirmation program. The performance confirmation program is discussed in Section 9.3, and the issue of access maintenance is discussed below.

#### 9.1.3.1 Continued Access of Main Drifts

During caretaker operation, access to the subsurface facility will be maintained. This activity involves the continued operation of utilities such as the ventilation system, lighting, electric power distribution, pumping, monitoring systems, and personnel transportation systems. Maintenance of access also requires upkeep of the drifts themselves. Supplementary ground support may be needed occasionally, and some major re-work of portions of the main accessways will likely be required. It is anticipated that a schedule of regular inspections of the accessible portions of the subsurface facility (i.e., all drifts not containing emplaced waste) will be developed and executed. Results of these inspections will prompt maintenance as needed to preserve access to the facility.

During the caretaker phase, the ventilation system will be reconfigured so that only one fan system is used. (During the active simultaneous development and emplacement phases, two separate and independent systems are employed.) The intake airflow from the surface will come down the north and south ramps and the former development exhaust shaft, flow along the main drifts, and exit the underground up the emplacement exhaust shaft. This process will maintain the facility's ability to limit airborne radionuclide release via the standby HEPA filtration facility on the surface at the emplacement exhaust shaft. A figure showing the configuration of ventilation flowpaths for the caretaker period is shown in Section 8.7.

#### 9.1.3.2 Continued Access of Waste Emplacement Drifts

The performance confirmation program, or other operational monitoring program, will provide the repository operator with input regarding the condition of the waste emplacement drifts. If unacceptable deterioration of portions of emplacement drifts is indicated by the monitoring program, remediation of those drift sections may be performed. This would involve cooling of the affected drift, removal of waste packages, and performance of the remedial activity.

Waste packages removed from an emplacement drift could be stored in an empty emplacement drift. It is anticipated that a small number of drifts, in addition to those minimally required to house the waste inventory, will be excavated and equipped for this purpose. The waste packages may be re-emplaced in the repaired drift, or left in the extra drift.

### 9.1.4 Summary

Very little design activity has been directed toward the caretaker period, primarily because no major technical uncertainties exist which are specific to this period, and because very little is known at this time about the requirements of the performance confirmation program. While issues such as gaining access to closed, heated emplacement drifts are of major technical interest, they are not specific to the caretaker phase. It is expected that, as performance confirmation issues become better defined, the caretaker phase will come into sharper focus, and specific requirements for this phase will be developed.

## 9.2 RETRIEVAL

The ability to retrieve any or all of the emplaced waste in the repository must be maintained for a period of time starting when the first waste package is emplaced and extending until the start of the closure operation. The length of the retrievability period is set at 50 years in 10 CFR 60. The DOE has extended this period of retrievability to 100 years from the emplacement of the first waste package (DOE 1994b).

A decision to retrieve the waste inventory could be prompted by either of two events:

- A loss of confidence in the site's ability to meet long-term performance requirements (cited in 10 CFR 60.111(b)(1))
- A determination that the recovery of valuable resources from the emplaced waste inventory is necessary.

The act of recovering the individual waste packages from the emplacement drifts will be discussed in this section.

### 9.2.1 Previous Work

Retrieval concepts developed for the potential repository at Yucca Mountain are extensively described in three CRWMS M&O documents briefly discussed below.

The retrieval of small waste packages from vertical boreholes located in the floor of each emplacement drift is discussed in *Alternatives for Waste Package Emplacement, Retrieval, and Backfill Emplacement* (CRWMS M&O 1993h). Among factors listed for normal retrieval were rock temperature, borehole condition, condition of the borehole liner, and radiation. Retrieval functions included access to the emplacement borehole, access to the waste packages, removal of the waste packages, and delivery of the waste to the surface facilities. Off-normal conditions that might impede retrieval were listed as a jammed isolation cover for a vertical borehole, jamming of emplacement and alignment rails and rollers caused by squeezing ground in the bored alcoves, derailing of the waste package carrier, and impacts on one or more waste packages due to ground failure. Possible causes were given as tectonics, variability in rock characteristics, human error, aging and corrosion of equipment and facilities, and radiolysis.

The concept of waste emplacement was changed from a small waste container emplaced in a vertical borehole to a large waste package emplaced horizontally in the emplacement drift as described in *Repository Retrieval Concepts and Operations Report* (CRWMS M&O 1994s). The large waste packages were changed to include either 12 or 21 PWR assemblies, 24 or 44 BWR assemblies, or some other combination for special wastes. The changes directly affected the emplacement drift opening size, waste package support apparatus, and radiation shielding/isolation of the overall underground layout. Three horizontal emplacement modes were discussed in this report including center-in-drift, off-center in-drift, and in-short perpendicular-alcove. A general operational approach for normal retrieval based on the three emplacement modes was prepared; it included identifying the reason for retrieval, beginning retrieval preparations, providing access to emplacement drifts, preparing emplacement drift, retrieving waste packages from emplacement drift, loading each waste package into a shielded waste package transporter, and transporting the shielded transporter and waste package to the surface. For abnormal (off-normal) conditions, additional steps were added that included assess nuclear safety, developing a retrieval plan, providing the required special equipment, implementing abnormal (off-normal) retrieval operations, and preparing emplacement drift to the extent allowed by conditions. Retrieval equipment and operations were general and programmatic in nature in this document and tended not to discuss specifics.

The largest bulk of current retrieval design was developed for the *Retrieval Conditions Evaluation* (CRWMS M&O 1995am). Design and operations in this document were based on the general layout configuration described in the *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design* (CRWMS M&O 1994a, Volume II) and an emplacement drift cross-section for a center-in-drift mode of waste emplacement. Specific operational sequence was given for normal retrieval while off-normal conditions and retrieval operations were more generally described. Only transporting equipment was described for normal waste emplacement and retrieval as the waste package car was shown to perform dual functions including that of transporter and support base. Special equipment for off-normal conditions was generally described as having grappling and shielding capabilities. These equipment and procedures have been largely carried forth through the advanced conceptual design.

### 9.2.2 Design Inputs

#### 9.2.2.1 Requirements

Retrieval of waste packages, if required, will be conducted in accordance to the following requirements as given in the RDRD (YMP 1994a):

### 3.2.1.3 CARETAKER PHASE REQUIREMENTS

When the repository has reached its legislated or physical capacity for waste disposal, it will be in the caretaker phase. The option to retrieve any and all emplaced waste will be preserved from the time of emplacement for up to 50 years. Performance confirmation will continue during this phase.

The GROA [geologic repository operations area] shall be designed so that until permanent closure has been completed, radiation exposures, radiation levels, and releases of radioactive materials to unrestricted areas will at all times be maintained within the limits specified in 10 CFR 20 and applicable environmental standards for radioactivity established by the EPA [U.S. Environmental Protection Agency] as listed in Section 3.2.2 of the RDRD (YMP 1994a).

### 3.2.1.4 RETRIEVAL PHASE REQUIREMENTS

The retrieval phase includes functions related to removing waste packages from the underground facility.

A. The repository shall be designed and constructed to permit the retrieval of any SNF [spent nuclear fuel] and HLW [high-level waste] emplaced in the repository, during an appropriate period of operation of the facility, as specified by the Secretary of Energy.

   This schedule applies to the first repository only. The CRWMS WA [waste acceptance] system element will begin accepting title to waste in 1998 and the disposal function will continue until all waste is disposed of (conceptually, in a second repository).

B. The GROA [geologic repository operations area] shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter until the completion of a performance confirmation program and NRC [U.S. Nuclear Regulatory Commission] review of the information obtained from such a program. To satisfy this objective, waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the NRC. 10 CFR 60.111(b)(3) gives guidance for developing the schedule.

### 3.2.2.5 CRITICALITY PROTECTION

A. All systems for processing, transporting, handling, storing, retrieving, emplacing, and isolating radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor must be sufficiently below unity to show at least a 5 percent margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

3.2.2.2.2 REPOSITORY SEGMENT – ENGINEERED BARRIER SEGMENT INTERFACE

The Repository Segment provides all mechanical, utility, logistics, safety, administrative, and mechanical support for the Engineered Barrier Segment. It also includes excavation and backfill machinery. The Engineered Barrier Segment has no inherent capability for these functions.

A. The Repository Segment provides systems and facilities in support of the functions and services shown in Table 3-6 [See Table 3-6 in the RDRD (YMP 1994a)].

B. The Engineered Barrier Segment outputs to the Repository Segment include heat [from nuclear waste], exhaust air, mechanical load, retrieved waste packages, and performance.

   3. The Engineered Barrier Segment shall be able to withstand shock [TBD] and vibration [TBD] levels characteristic of handling, emplacement, retrieval and seismic environments, without adverse impacts on waste containment and isolation capability.

3.2.5.1 RELIABILITY

The Repository Segment shall provide a fault-tolerant (or fail-safe) system that allows for the continued management, handling, transfer, storage, emplacement, retrieval, and isolation of SNF [spent nuclear fuel] and HLW [high-level waste] in a safe manner that optimally protects health, safety, and the environment under all operational conditions. Nothing in this section shall be construed to indicate that NRC [Nuclear Regulatory Commission]-mandated redundancy of systems may be neglected.

3.7.4.1 WASTE HANDLING REQUIREMENTS

A. Waste Handling

   4. The facilities and equipment used for waste-handling operations shall be designed so that waste-handling operations can be performed in reverse order to permit retrieval of emplaced waste packages.

3.7.5 REPOSITORY UNDERGROUND REQUIREMENTS

D. Retrieval of Waste. The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of 10 CFR 60.111.

E. Underground Openings

   1. Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

#### 9.2.2.2 Assumptions

Retrieval may be necessary or required, as stated in the *Controlled Design Assumptions Document* (CDA) (CRWMS M&O 1995a), Key Assumption 016:

> The repository will be designed for a retrievability period of up to 100 years after initiation of emplacement.

### 9.2.3 Retrieval Description

Retrieval time, as required by the RDRD (YMP 1994a), will include the combined period to construct the repository and emplace the contained waste (YMP 1994a). Retrieval of all waste packages and other nuclear wastes is estimated to not exceed 34 years from the date of the directive to retrieve (CRWMS M&O 1994s).

#### 9.2.3.1 Retrieval Under Normal Conditions

Waste package retrieval logistics under normal conditions will essentially be the reverse of waste package emplacement operations as described in Section 8.6.3.2.1. Access to the upper block emplacement drifts will be provided by the east and west service main drifts through which both emplacement and retrieval will be conducted. To remove waste packages from any particular drift, pre-retrieval and retrieval activities will be performed. Pre-retrieval activities will include initiating ventilation in the waste emplacement drift, confirming that no debris obstructs equipment operation, and monitoring drift temperature until it is within prescribed limits. Normal retrieval may be conducted simultaneously from the east and west service main drifts on both sides of the upper emplacement block. Approximately four weeks prior to retrieval, the shield door of the specified emplacement drift will be opened and cooling by ventilation will occur. Cooling for retrieval is discussed in Section 8.7.

Normal retrieval will be performed from both the east and west sides of the upper emplacement block and from the west side of the lower emplacement block while following a well-defined procedure as described below:

**Travel to the Emplacement Drift –** The retrieval locomotive will be placed atop a locomotive carrier and pushed by a transfer locomotive along the inside track of the service main drift to the turnout of a specific emplacement drift. The train will be parked while the track switch is changed to the closed position that allows the rail traffic to enter the turn. The transfer locomotive will push the carrier over the switch and around the curve. After the transfer locomotive has pushed the carrier into the curve, the switch in the service main drift will be changed to the open position so that rail conveyances following the emplacement train can pass the emplacement drift unimpeded. The carrier and transfer locomotive will continue through a second switch which will place the train on one of two parallel tracks that will be designated as the waste emplacement track. The train will continue until the rails on the locomotive carrier mate with the rails of the emplacement drift. As noted earlier, the shielding doors will be in the open position for cooling.

**Removal of Waste Package from the Emplacement Drift** – The retrieval locomotive atop the locomotive carrier will activate and move into the emplacement drift and travel through the drift to the first waste package in line. The retrieval locomotive will couple with the waste package railcar, deactivate the brake mechanism, and pull the waste package and railcar to the entrance of the emplacement drift where the waste package loading mechanism engages the railcar and secures it until ready to load into the waste package transporter. The retrieval locomotive decouples from the railcar and passes through the emplacement drift opening to the travel position on the locomotive carrier. The transfer locomotive, retrieval locomotive, and retrieval locomotive carrier leave the cross-cut area in the same manner in which they entered and move onto the track in the main service drift. The track switch is opened and the train proceeds past the cross-cut opening to allow entry of the primary locomotive and the waste package transporter.

**Removal of the Waste Packages from the Repository** – The primary locomotive will push the waste package transporter into the cross-cut drift, around the curve, and abut to the step-up of the emplacement drift where the braking mechanisms on both are activated. The waste package and supporting railcar are pulled forward by the waste package loading mechanism until the transporter's internal handling mechanism engages the waste package and railcar. Both are pulled into the transporter. The loaded waste package transporter is withdrawn from the cross-cut drift and pulled through the service main drift and up the north ramp to exit the repository.

The above steps are repeated until all waste packages have been removed from the emplacement drift.

#### 9.2.3.2 Retrieval Under Off-Normal Conditions

##### 9.2.3.2.1 Description of Potential Off-Normal Conditions

Off-normal conditions in the underground repository are the result of events that deviate from the predicted behavior of the repository host rock, engineered structures and facilities, or operations. Each such condition may be caused by natural or manmade processes that have performed unexpectedly, either as an event which has accelerated beyond expected deterioration rates or which has failed in a sudden, catastrophic manner. Potential off-normal conditions considered to most affect retrieval of waste packages are discussed below.

**Deterioration of Drift Inverts Causing Track Failure** – The drift invert is installed to support the rail, conveyances, and loads that will be associated with each emplacement drift. The combined estimated load of the railcar and largest waste package is 82.5 metric tons. Two alternative designs include an invert of crushed tuff or similar material that is dumped, planed, and compacted and an invert which is composed of cast-in-place concrete.

Deterioration of an invert of compacted fill will likely be a normal time-dependent process of settlement in which the track ties settle non-uniformly. Little if any settlement is expected to occur during the caretaker period, however. Deterioration of a concrete invert is expected to be generally a time-temperature-humidity process in which decomposition of the hydrated phases, deterioration of the aggregate, and thermal incompatibilities between the paste and the aggregate cause changes in concrete strength and elasticity. While the maximum predicted temperature at the drift floor for a thermal loading of 100 MTU/acre has been calculated to be about 170 to 179°C in 67 to 87 years after emplacement, appreciable deterioration of the concrete due to temperature alone is unlikely to occur as the compressive strength of concrete will be maintained up to about 300°C (CRWMS M&O 1995am).

#### 9.2.3.2.2 Waste Package Removal During Off-Normal Conditions

Waste packages may be removed from emplacement drifts during off-normal conditions that may require extraordinary efforts to extract the waste packages. Suggested methods for waste package removal are discussed below.

##### 9.2.3.2.2.1 Retrieval after an Emplacement Drift Rockfall

Rockfall is an off-normal event in an emplacement drift. The number and severity of rockfalls that may occur are tied to the frequency distributions of occurrence, location, and size of the rockfalls. While rockfall events are not currently definitive, the possibility that such events will occur mandates potential solutions to various resulting scenarios. These solutions are described in the preliminary procedures for various failure scenarios given below.

**Unaffected Waste Packages** – Ventilation will be established to provide a cooling airflow if air can pass through the emplacement drift to the exhaust drift following a rockfall. Normal recovery of all waste packages on the service main drift side of the rockfall will be performed when an acceptable re-entry temperature of about 50°C is achieved. The rockfall will be evaluated via mobile remote television arrangement or manned, shielded vehicle to assess required actions. The fallen rock and accompanying debris (bolts, mesh, steel sets, etc.) will be removed by remote-controlled equipment in a six-step process as shown in Figure 9.2.3-1. After the rockfall is cleared, the remaining waste packages can be removed. Ground control remediation can then proceed.

**Covered Waste Packages** – Ventilation will be established to provide a cooling airflow if air can pass through the emplacement drift to the exhaust drift following a rockfall. Normal recovery of all waste packages on the service main drift side of the rockfall will be performed when an acceptable re-entry temperature is achieved. The rockfall will be evaluated via mobile remote TV arrangement or manned, shielded vehicle to assess required actions. The fallen rock and accompanying debris (bolts, mesh, steel sets, etc.) are removed by remote-controlled equipment using care to separate the rockfall material from the waste package which will be buried amid the debris. If required, large boulders will be reduced in size as shown in Step 3 of Figure 9.2.3-1 and gathered in accordance with Step 6. Specialized equipment which is not shown may be used to recover waste packages from beneath large rockfalls which cannot be reached by the impact hammer or loader shown in Figure 9.2.3-1. Grappling eyes may be spot welded to the exposed end of the waste package or railcar by a remotely-controlled welder and the waste package is winched from beneath the rock. The waste packages will be then removed from the emplacement drift so that remote-controlled equipment can completely clear the track.

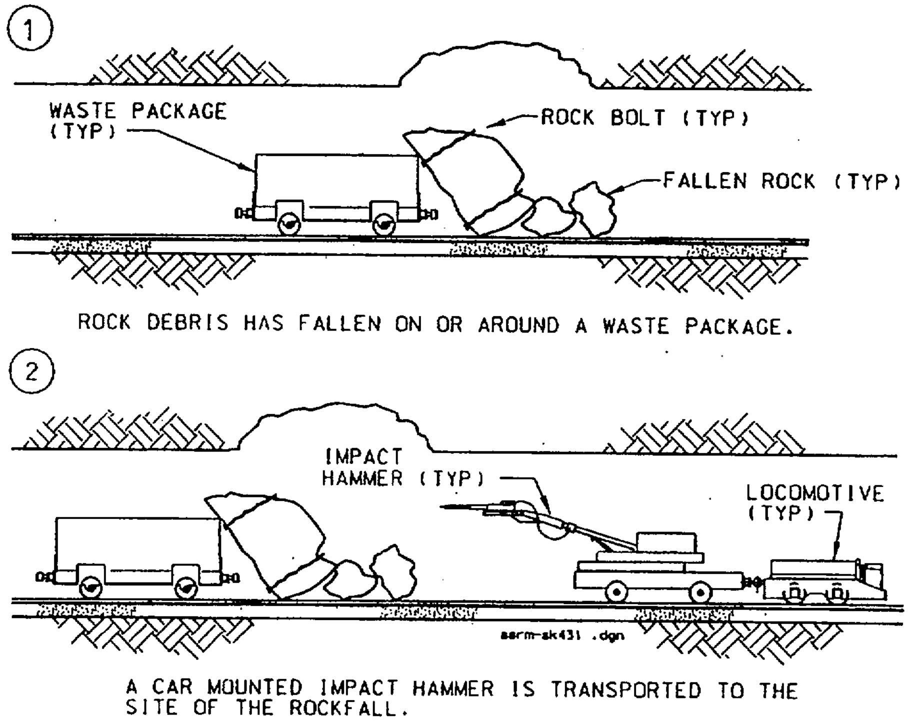


Figure 9.2.3-1. Off-Normal Retrieval Operation with Rockfall

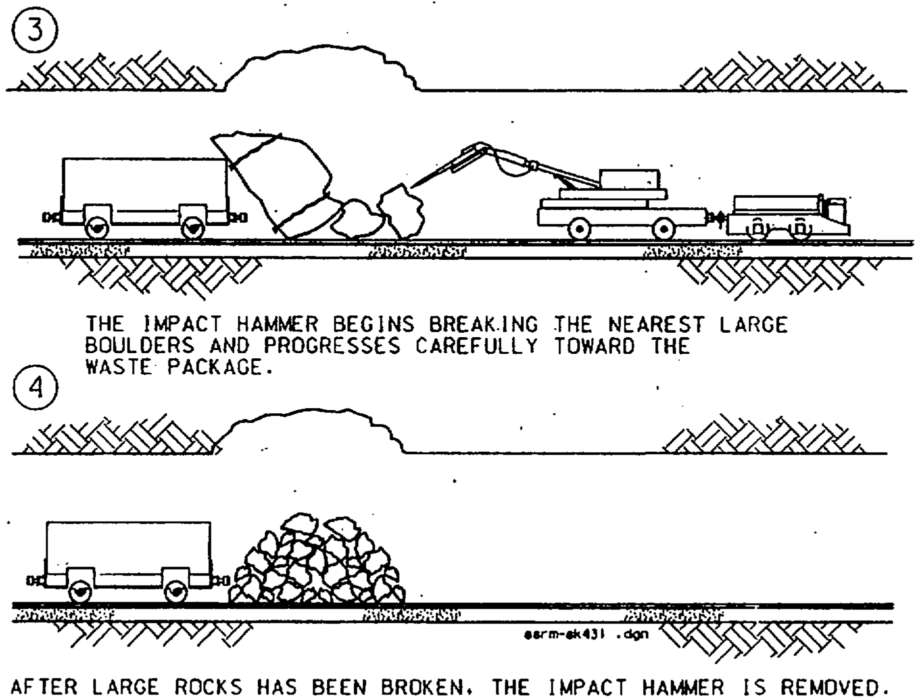


Figure 9.2.3-1. Off-Normal Retrieval Operation with Rockfall (Continued)

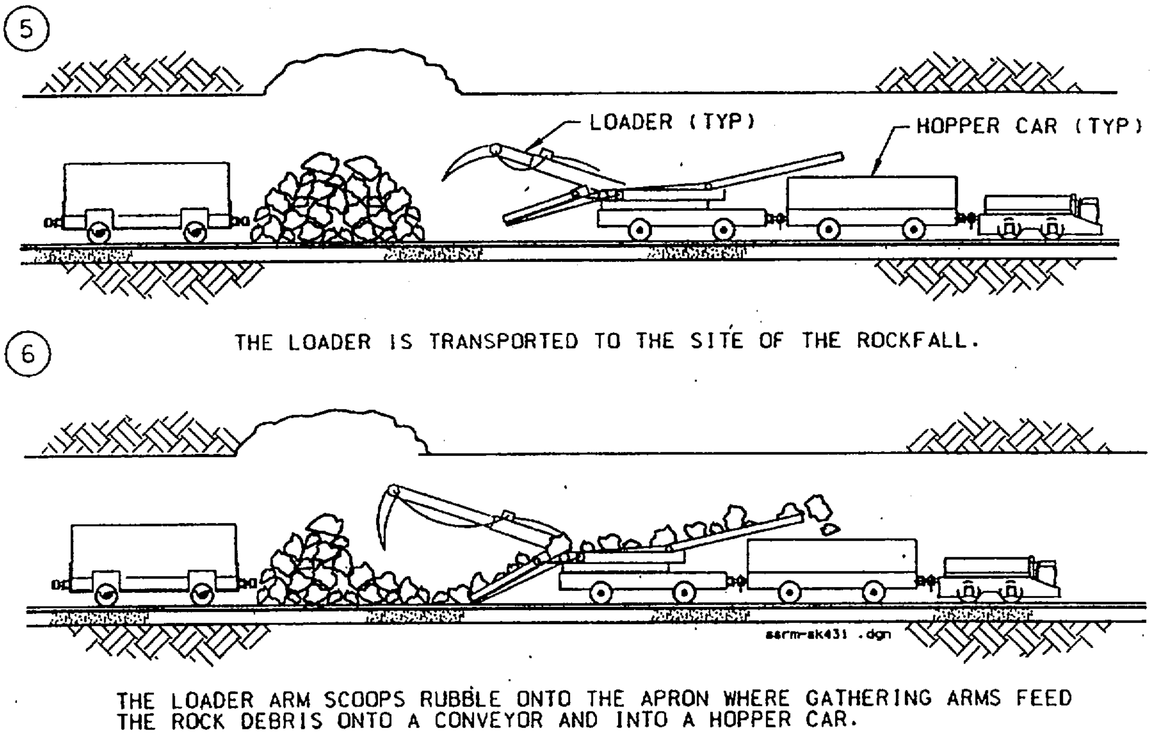


Figure 9.2.3-1. Off-Normal Retrieval Operation with Rockfall (Continued)

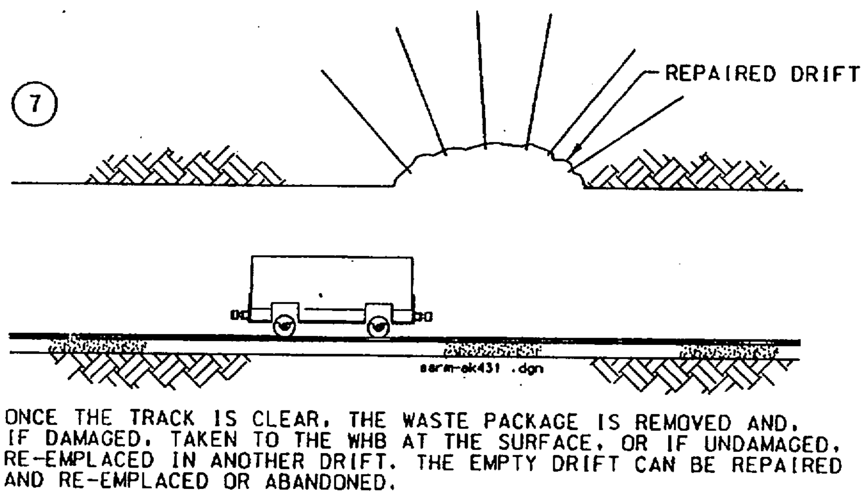


Figure 9.2.3-1. Off-Normal Retrieval Operation with Rockfall (Continued)

**Blocked Airway** – A portable fan will be placed in the tunnel boring machine launch main to pull air through tubing or a duct to the point of obstruction. The ventilation tubing will be added section by section as the drift cools. The tubing advance will be coordinated with waste package removal. As the area around a waste package is cooled, the waste package will be removed as described above. An additional section of tubing will be added as each waste package ahead of the rockfall is retrieved.

This method is likely to take longer than will be required for normal ventilation due to the limited amount of air that will be provided for cooling and the delay required to advance the tubing.

The rockfall will be evaluated and removed as previously described.

**Breached Waste Package** – The breaching of a waste package may occur as a result of partial or total crushing, penetration due to a shard forced into the interior of a waste package, or defects in the waste package. While such an event is very unlikely, the impact is so great on the subsurface operations that retrieval of a breached waste package must be addressed.

Detection of contamination anywhere in the subsurface will initiate an immediate decrease in air flow as high-efficiency particulate air filters begin to operate (see Section 8.7), cessation of subsurface activities, and evacuation of personnel. Remote monitoring will be conducted to determine the appropriate area or specific point of contamination before suitably protected personnel re-enter the repository to effect repairs. A considerable length of time may be required to locate the breached waste package or packages especially if the contamination detected is being carried in air leakage from a closed emplacement drift. After the contamination has been located, the affected drift will be cooled using the minimum air flow needed. Retrieval of unaffected waste packages will be performed while using remote monitoring to evaluate each waste package prior to recovery. When the source waste package is encountered, the rockfall debris will be pushed aside, if possible, so that the waste package can be retrieved before removing the rock. The damaged waste package will be pulled into a special transporter and moved to the surface waste handling building for special handling. The rock debris will be removed and the area around the waste package position cleaned of all contamination. All affected materials will be treated as contaminated waste products and disposed accordingly.

#### 9.2.3.2.2.2 Retrieval After Damaged Rail System

A crawler-mounted, low-boy transporter will be used to pass over the damaged rail section, grapple and winch each waste package, and remove the waste packages individually from the affected emplacement drift until a sufficient number of waste packages have been removed to permit track repair by personnel behind shielding. Rail system damage due to rockfalls or package removal will be repaired by straddling the track, cutting away affected rail clips and joining splines (fish plates), lifting the damaged rail section, and replacing with a new rail section complete with rail, fish plates, and track bolts. After the track has been replaced, the remaining waste packages may be removed using normal procedures.

#### 9.2.3.2.2.3 Retrieval With an Inoperative Railcar

A typical railcar may become immobile due to corrosion bonding of the wheels to the track or the inability of the wheel axles to turn in the bearings. Three progressive courses of action will be employed: the retrieval locomotive will nudge the railcar in an attempt to free the wheels; a second and/or larger retrieval locomotive will couple to the first locomotive which is coupled to the railcar and attempt to pull the railcar from the emplacement drift; and the car will be grappled and winched either onto a low-boy trailer or dragged from the drift if all else fails.

#### 9.2.3.2.2.4 Retrieval With a Derailed Railcar

Spreading or misalignment of the track or seismic activity will be the probable cause of a derailed railcar. Severely damaged rail segments leading to the waste package will be replaced. Otherwise, a track mounted crane or robotic arm will approach the derailed waste package with a track rerailer and place the rerailer adjacent to the leading railcar wheel flange on each rail. An attachment with cable will mate with the railcar coupler and the entire railcar unit will be pulled so that the forward wheel flanges roll up the rerailer and onto the track. The entire car length will be slowly pulled past the rerailer to ensure that all wheels are securely on the track. The waste package will then be retrieved in accordance with normal operations.

A derailed railcar weighing to 81 tons (waste package and railcar combined weight) could likely require a greater tractive effort than may be exerted by emplacement or special application locomotives. For such an event, a special self-propelling conveyance with winch and anchor may be developed which will couple with the derailed car and pull the car up the rerailer by winching toward the anchor point.

### 9.2.4 Retrieval Equipment

#### 9.2.4.1 Equipment for Normal Conditions

Equipment used for normal retrieval will be identical to those specific items identified for waste emplacement in Section 8.6.4. Retrieval equipment includes locomotives (waste package transporter unit, transfer unit, retrieval unit), carriers (waste package transporter, retrieval locomotive carrier, and waste package railcar), railcar mover, and loading/unloading mechanism. Equipment operation during retrieval of waste packages will conform to those procedures previously identified for waste emplacement.

#### 9.2.4.2 Special Equipment for Off-Normal Conditions

Off-normal conditions as previously described will require specialized equipment that is maintained and readily available for events classified as off-normal. Functions to be performed include the clearing of rock debris, repair of damaged track, rerailing of waste package cars, removal of disabled railcars, and cleanup of released radioactive waste products from damaged containers. While the equipment to perform these functions has not been designed, the activities that certain special equipment might perform is described below.

To clear rock debris, equipment must be able to handle large slabs lying on waste packages as well as small boulder-sized pieces strewn about the track and waste package. A potential unit might include a long folding or retractable arm capable of extending over the top of a waste package. Attachments to that arm will include a detachable impactor for breaking, as shown in Figure 9.2.3-1, and/or a claw for grasping and pulling, which is not shown. Large boulders will be reduced in size by the impactor. Each attachment will be interchangeable. The unit will be rail-mounted. A second unit will have a gathering apron extending across the full width of the track to collect large rock debris and two articulating arms that reach out and pull debris onto the gathering apron. Rock debris, after being collected upon the apron, will be moved by a drag chain flight conveyor to a collection hopper at the rear of the unit. Only debris that impedes passage of rail conveyances needs to be removed.

To repair damaged track, tasks generally include tamping of ties (if compacted fill or ballast is used), jacking to lift rail and ties, distribution of ballast (invert material), lining of track, attaching rail to ties, and joining rail segments. In lieu of an overhanging crane that may not perform well due to the space constraints in underground openings, a crawler-mounted unit that straddles the track may be used. The track repair unit might include a rotating magazine for holding new rail segments, a track gauger, tie tamper, power jacks, ballast distributor, tie spacer, and bolt driver and tightener.

#### 9.2.4.3 Remote Handling

Many off-normal retrieval conditions will require remotely controlled equipment to perform one or more various retrieval activities including removal of fallen rock and drift support appliances (if applicable), repair of damaged rail sections, rerailing of railcar and waste package units, dragging or lifting inoperative railcars and waste packages upon carriers, cleanup of spilled radioactive material from breached waste packages, and recovery and replacement of invert sections contaminated by breached waste packages. Equipment systems incorporating remote handling functions will include operator control stations, wireless communication networks, video monitors, and various sensing devices described in Section 8.6.5.

## 9.3 PERFORMANCE CONFIRMATION

Performance confirmation is a program of baseline data acquisition and ongoing monitoring that ensures assumptions made during the repository licensing process are correct and confirms that the repository system is functioning, and will continue to function, as it was presented at the time of licensing.

### 9.3.1 Previous Work

Requirements to guide the development of a performance confirmation program are not yet in place. For this reason, there has been very little design effort expended on performance confirmation program development. However, data are being collected, both from the Exploratory Studies Facility and the surface-based testing programs, that will provide much of the baseline information needed to initiate the formal performance confirmation program once it is developed.

A performance confirmation systems study is underway during FY 1996. The objective of the study report is to provide the technical bases for recommendations for performance confirmation program-related updates to the *Repository Design Requirements Document* (RDRD) (YMP 1994a) and/or *Engineered Barrier Design Requirements Document*, (EBDRD) YMP 1994c)(with primary emphasis on the identification of the important issues. The report will also contain an overview of the performance confirmation approach in the form of a draft *Performance Confirmation Plan*. This study is the first step in defining the requirements for the performance confirmation program.

### 9.3.2 Design Inputs

All text in this section is excerpted directly from the RDRD (YMP 1994a), the reference source for repository requirements. Upper-level requirements from within the program (i.e., CRWMS upper-level requirements) and outside the program (such as 10 CFR 60 requirements) are included in the RDRD (YMP 1994a). The specific requirements quoted below are considered applicable to aspects of the caretaker function. Other requirements of the RDRD (YMP 1994a), which may apply in a more general way, are not included here.

3.7.6 PERFORMANCE CONFIRMATION REQUIREMENTS

A. General Requirements.

1. The GROA [geologic repository operations area] shall be designed to include the capability to support tests appropriate or necessary (as determined by the NRC [U.S. Nuclear Regulatory Commission]) for the administration of the regulations of 10 CFR 60. These tests may include tests of

   a) radioactive waste,

   b) the geologic repository including its SSCs [systems, structures, and components],

   c) radiation detection and monitoring instruments, and

   d) other equipment and devices used in connection with the receipt, handling, or storage of radioactive waste.

2. Environmental monitoring equipment shall be provided to acquire baseline data for performance confirmation.

3. The tests required in Section 3.7.6.A.1 shall include a performance confirmation program carried out in accordance with Subpart F of 10 CFR 60.

4. The performance confirmation program shall provide data that indicates, where practical, whether:

   a) Actual underground conditions encountered and changes in those conditions during construction and waste emplacement operations are within limits assumed in the licensing review; and

   b) Natural and engineered systems and components required for repository operation, or that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

5. The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as appropriate, to accomplish the objectives stated in Subpart F of 10 CFR 60 (3.7.6.A.2) above.

6. The program shall:

   a) Not adversely affect the ability of the natural and engineered elements of the geologic repository to meet the performance objectives.

   b) Provide baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

   c) Monitor and analyze changes from the baseline condition of performance of the geologic repository.

   d) Provide an established plan for feedback and analysis of data, and implementation of appropriate action.

7. The Repository Segment shall be capable of monitoring underground conditions and evaluating them against design assumptions.

B. Testing. During the early developmental stages of construction, a program of in situ testing of such features as borehole and access seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

C. Rock Measurements. The Repository Segment shall be capable of measuring, as a minimum, rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into underground areas, changes in groundwater conditions, rock pore water pressures, including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

D. Thermomechanical Response. The Repository Segment shall be capable of in situ monitoring of the thermomechanical response of the underground facility until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

E. Laboratory Experiments. To support the waste package monitoring program required by 10 CFR 60.143(a) and (b), the GROA [geologic repository operations area] shall be designed to include facilities (to the extent appropriate for on-site work) capable of supporting laboratory experiments that focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the underground facility during the waste package monitoring program shall be duplicated in the laboratory experiments.

F. Backfill Test. A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

G. Borehole and Access Seal Tests. Test sections shall be established to test the effectiveness of borehole and access seals before full-scale operation proceeds to seal boreholes and accesses.

The CDA Document (CRWMS M&O 1995a) contains assumptions that are related to the Performance Confirmation Program that influence the design. These assumptions are Key 053, Key 054, and DCS 013.

### 9.3.3 General Description

As noted above, there has been essentially no design effort expended on performance confirmation, and no description of the performance confirmation program is available. The extent of the program, the types of data to be collected, and the collection interval needed remain largely unknown. As required by 10 CFR 60.72, records will be kept of conditions encountered during the construction of the repository. It is not known whether the acquisition of these data will be considered as part of the performance confirmation program or simply a required function of repository construction. 10 CFR 60.141 requires that the information acquired during repository construction and operation be utilized to confirm or provide the basis for change of the data which were used during the design and licensing of the facility. The evaluation of the data will be a central function of the performance confirmation program.

The program may or may not involve the periodic recovery of emplaced waste packages for inspection and/or testing. If all emplacement drifts required continuous monitoring, the operational impacts would be severe. However, if only selected drifts are continuously monitored, or if all drifts are monitored intermittently by mobile remote data acquisition units, the impacts to repository operations would be lessened. The approach will be consistent with the concept of operations that is shown in the CDA Document (CRWMS M&O 1995a).

### 9.3.4 Summary

As requirements are defined for the performance confirmation program, the questions of areal coverage, monitored parameters, and frequency/method of measurement will be better defined.

## 9.4 CLOSURE

The closure phase of the repository starts after the caretaker phase and retrieval phase (if required). Closure of the repository begins when the Nuclear Regulatory Commission amends the license to authorize permanent closure. During this phase of operation, portions of the underground facility will be backfilled and sealed. Surface facilities will be decontaminated and dismantled or converted to other uses. A protective system of physical and institutional barriers will be established (CRWMS M&O 1995a).

### 9.4.1 Previous Work

The closure design is currently limited and incomplete; previous work has provided only tentative goals and general methodology. The *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design* (CRWMS M&O 1994a) identified the need for backfilling and sealing of primary underground openings and discussed various general considerations including selection and placement of backfill materials.

Preliminary sealing and backfilling concepts for repository closure were developed in a program by Sandia National Laboratories. The work by Sandia has largely been consolidated in two publications which are briefly discussed below.

In *Initial Field Testing Definition of Subsurface Sealing and Backfilling Tests in Unsaturated Tuff* (SNL 1993c) Sandia identified and described several field tests to evaluate the performance of sealing components. These components included shaft, ramp, and borehole seals and associated fill; drift fill and seals; and Topopah Spring member host rock. Two sets of testing were proposed. In the first set, seal component testing was proposed that included small-scale in situ test, intermediate-scale borehole seal tests, fracture grouting tests, surface backfill tests, and grouted rock mass tests. This testing will be followed by performance confirmation testing and will include seepage control tests, backfill tests, bulkhead testing in the Calico Hills unit, large-scale shaft seal and shaft fill tests, and remote borehole sealing tests. In this 1993 publication, uncertainties associated with the sealing components emplacement and performance were summarized.

In *A Review of the Available Technologies for Sealing a Potential Underground Nuclear Waste Repository at Yucca Mountain, Nevada* (SNL 1994) Sandia discussed the results of a broad study of determining whether or not seals for shafts, drifts, and boreholes can be placed with reasonably available technology. The scope of the study was to review selected sealing case histories through literature searches and site visits, determine whether reasonably available technologies exist to seal a potential repository at Yucca Mountain, and identify any deficiencies in existing sealing technologies. The study concluded that available technologies or easily developed new technologies were adequate in four key areas and that adequate technology does not exist in two key areas. These areas are summarized as follows:

- Available Technology

  - Technology for placement of general backfill in underground openings. Under moderate temperature conditions that are below 38°C, off-the-shelf technology is available and is being routinely used in many operations. Backfill is also routinely placed and compacted on the surface to exacting specifications during civil construction.

  - Technology exists for the placement of large-scale bulkheads in underground shafts and drifts at moderate temperatures.

  - Technology exists to place grout in fractured rock masses at moderate temperatures.

  - Technology exists or could be easily developed to precondition areas where seal components are to be placed.

- Unavailable Technology

  - Technology does not currently exist to demonstrate the long-term durability and performance of seal components.

  - Case histories are not available that adequately document sealing component placement or performance under greatly elevated temperatures, high-radiation environments, and potentially unstable underground openings.

### 9.4.2 Design Inputs

#### 9.4.2.1 Requirements

All text in this subsection is directly excerpted from the RDRD (YMP 1994a), which documents the requirements for repository design. Upper-level requirements from within the program (i.e., CRWMS upper-level requirements) and outside the program (e.g., 10 CFR 60 requirements) are included in this requirements document. The specific requirements quoted below are considered applicable to the closure aspects of the repository. Other requirements from the RDRD (YMP 1994a), which may apply in a more general way, are not included in this section.

3.1.1.3.4 MONITOR PERFORMANCE – FUNCTION 1.4.4.4

This function includes planning for long-term monitoring of the performance of the geologic repository after it has been permanently closed.

3.1.1.4 CLOSE MINED GEOLOGIC DISPOSAL SYSTEM – FUNCTION 1.4.5

This function includes permanent closure of the repository to human access. This may include final backfilling of all or part of the underground facility (if deemed necessary by analysis and authorized by the license), closing and sealing openings (ramps, shafts, and boreholes), decommissioning surface facilities, reclaiming the site, and establishing institutional barriers. This does not preclude partial backfilling before permanent closure. This function begins upon approval of the license amendment for permanent closure and continues until the last institutional barrier is established and the license is terminated. Provisions may be added for post-permanent closure monitoring.

3.1.1.4.1 CLOSE UNDERGROUND OPENINGS – FUNCTION 1.4.5.1

This function includes final backfilling of the remaining open operational areas of the underground facility and boreholes after the termination of waste emplacement. It includes removing underground equipment, backfilling underground openings, and the sealing of shafts and ramps.

3.1.1.4.2 DECOMMISSION SURFACE FACILITIES – FUNCTION 1.4.5.2

This function includes the permanent removal from service of surface facilities and components (necessary for preclosure operations only) after repository closure, in accordance with regulatory requirements and environmental policies. It includes decontaminating, dismantling, and removing facilities and reclaiming the site.

3.1.1.4.3 ESTABLISH INSTITUTIONAL BARRIERS – FUNCTION 1.4.5.3

This function includes establishing active and passive institutional controls for restricting access and avoiding disturbance to the MGDS controlled area and minimize or prevent intentional and unintentional activities in and around the MGDS that could breach the barrier systems for at least 1,000 years.

3.1.1.4.4 RECLAIM SITE – FUNCTION 1.4.5.4

This function includes actions taken to restore the MGDS site to as close as practicable to its original undisturbed condition.

3.2.1.4 RETRIEVAL MODE REQUIREMENTS

C. The GROA [geologic repository operations area] shall be designed so that until permanent closure has been completed, radiation exposures, radiation levels, and releases of radioactive materials to unrestricted areas will at all times be maintained within the limits specified in 10 CFR 20 and applicable environmental standards for radioactivity established by the EPA [U.S. Environmental Protection Agency], as listed in Section 3.2.2.

### 3.2.1.5 CLOSURE AND DECOMMISSIONING MODE REQUIREMENTS

When the NRC [U.S. Nuclear Regulatory Commission] amends the repository license to authorize permanent closure, the underground facility will be backfilled (if required and authorized) and sealed; the surface facilities will be decontaminated and dismantled or converted to other uses.

The final state of the GROA [geologic repository operations area] shall conform to plans approved as part of the license for permanent closure and decontamination and dismantlement of surface facilities.

### 3.2.1.6 POSTCLOSURE MODE REQUIREMENTS

This mode begins at permanent closure and includes the isolate waste function and any residual functions such as maintaining the institutional barriers and performance confirmation.

A. The repository shall include facilities with the capability of implementing a post-permanent closure monitoring program in accordance with the application to amend the license for permanent closure.

B. The repository shall identify the controlled area and the GROA [geologic repository operations area] by monuments that are designed, fabricated, and emplaced to be as permanent as practicable.

C. The disposal system shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table A-1 of Appendix A of 40 CFR 191; and have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table A-1 of Appendix A of 40 CFR 191. [TBR]

D. Facilities shall be provided to support active institutional controls at the repository site, including physical barriers to human intrusion and maintenance facilities. [TBV]

NOTE: CDA (CRWMS M&O 1995a) contains clarifying language for this requirement (RDRD 3.2.1.6.D)

### 3.7.4.4 OTHER SURFACE FACILITIES

L. Decontamination and Dismantlement.

1. Surface facilities shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of NRC [U.S. Nuclear

Regulatory Commission] regulations, with respect to equivalent activities licensed thereunder.

2. The SSCs [systems, structures, and components] shall include features that will facilitate decontamination for future decommissioning, increase the potential for other uses, or both.

### 3.7.5 REPOSITORY UNDERGROUND REQUIREMENTS

J. Seals.

1. Seals for accesses and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure.

2. Materials and placement methods for seals shall be selected to reduce, to the extent practicable, (a) the potential for creating a preferential pathway for groundwater to contact the waste packages; or (b) for radionuclide migration through existing pathways.

3. The seals for accesses and boreholes shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to applicable environmental standards for radioactivity established by the EPA with respect to both anticipated processes and events and unanticipated processes and events.

### 3.7.6 PERFORMANCE CONFIRMATION REQUIREMENTS

G. Borehole and Access Seal Tests. Test sections shall be established to test the effectiveness of borehole and access seals before full-scale operation proceeds to seal boreholes and accesses.

## 6.1 GLOSSARY

Decommission means to remove (as a facility) safety from service and reduce residual radioactivity to a level that permits release of the property to unrestricted use and termination of license.

Permanent closure is final backfilling of the underground facility and the sealing of shafts and boreholes.

#### 9.4.2.2 Assumptions

Permanent closure of the repository begins after the completion of emplacement of all scheduled radioactive waste and after a specified waiting period during which retrieval is possible in accordance with the MGDS Concept of Operations in the CDA.

Surface decommissioning includes decontamination, dismantlement, facility removal activities, and site reclamation. Institutional barriers include land records and warning systems that will be placed around the repository site to prevent human disturbance.

Subsurface closure involves removing underground equipment, backfilling of main drifts, sealing, and implementing a postclosure monitoring system to serve the performance confirmation program. If backfilling of emplacement drifts is to be performed, the closing process will start with cooling of the emplacement drifts for inspection. Drift inspection may include repairing ground support systems if deemed necessary.

### 9.4.3 Backfill and Sealing

Backfilling is currently planned as part of the activities associated with closure of the repository. Backfilling as set forth in the CDA will be performed throughout the ramps, shafts, and main service drifts.

Backfilling will be a part of the sequence of closing subsurface openings which involves removing underground equipment, preparing the main openings to receive backfill, backfilling the main openings, emplacing repository seals, and implementing postclosure monitoring (if required). Items to be removed prior to backfilling will include equipment, rail, utilities and support services, and unsuitable materials. Many of these items will be needed to support backfilling and sealing operations. In addition, certain utilities and support items, such as ventilation duct, will be temporarily installed during backfilling and sealing and will be removed when no longer needed. Preparing the openings to receive backfill includes installing utilities and equipment specifically dedicated to backfill operations.

Seals will be placed only in the ramps, shafts, and boreholes in accordance with the MGDS Concept of Operations in the CDA. The seals will be strategically located to lessen radionuclide migration over extended time frames, will likely be integrated with closure backfilling in accordance with the CDA, and will be bracketed by the backfill. Placement of seals will involve preparing the underground openings to receive the seals, obtaining and transferring seal material, and constructing the seals.

Emplacement of backfill and seals will likely be performed in a series of parallel operations commencing with backfilling of the main service drifts adjacent to the waste emplacement drifts in the lower block and continuing through closure of shafts and ramps. Because backfilling will be a retreating operation, material will be stowed at the extremities of the repository and progress back to the surface openings while maintaining sufficient access and ventilation to maintain personnel and equipment. Initially, the established ventilation base for the caretaker period will be modified as main drifts are plugged so that ventilation will eventually be provided to working headings through ducts.

### 9.4.3.1 Backfill Transportation and Handling Equipment

#### 9.4.3.1.1 Surface Backfill Handling

Backfilling as described in the CDA involves the full range of activities from obtaining material from the surface stockpile or other source, processing (screening, crushing, and possibly, washing) to obtain the required grading, placing the processed material into a stockpile for subsequent loading, and transferring the material to the openings for placement (CRWMS M&O 1995a). Design relating to backfill surface facilities has not been prepared due to several unspecified factors including the unknown amount of material degradation and settlement following a 100-year storage period, the undecided choice of using a single or multiple component fill material, and the unknown required backfill emplacement rate. Surface equipment will include loading, hauling, and processing equipment as discussed in Section 8.8.4.1. This equipment is common for both backfilling of emplacement drifts (if required in the future) and of main drifts and ramps.

A secondary concern of using TSw2 tuff excavated from the repository is the potential of reintroducing the excavated rock enriched with organic and inorganic nutrients after 100 years of surface exposure that might support and nourish various species of microorganisms capable of promoting waste package corrosion. In addition to the possible removal of deleterious fines, washing plus chemical treatment may be considered to render the backfill material sterile to microbial use.

Haul trucks will be used to transport backfill material to the shaft sites which will be located in the rugged terrain upslope.

#### 9.4.3.1.2 Underground Backfill Handling

Backfill material will be transported underground by open gondola railcars as discussed in Section 8.8.4.1.

Backfilling will likely be performed in multiple locations to reduce the required time. Approximately 2.6 million cubic meters of material will be required (as shown in Table 9-1) in the service main drifts, shafts, and miscellaneous underground excavations. Backfilling will be conducted simultaneously in both shafts and at two underground locations. Two or three backfill units are the probable number that can be operated and maintained on a routine basis. To supply these locations, two transfer points will be installed to unload gondola cars and to load stower supply cars.

Table 9-1. Required Backfill Volume for Closure

| Excavation | Drift/Shaft Length (m) | Required Fill Volume ($m^3$) |
|---|---|---|
| 9.00-m diameter tunnel boring machine | 11,350 | 684,000 |
| 7.62-m diameter tunnel boring machine* | 21,730 | 906,000 |
| Mobile miner | 22,770 | 960,000 |
| Drill and blast | 80 | 5,000 |
| Shafts | 700 | 25,000 |
| Total | | 2,580,000 |

* Includes excavation performed for ESF

### 9.4.3.2 Backfill Placement Equipment

#### 9.4.3.2.1 Backfill Stowing Equipment Description

Pneumatic stowing is currently the preferred method to emplace backfill material in the service main drifts and ramps as well as around ramp seals due to the large volume of material that can be moved, the potential for completely filling the drift, the shorter time required to emplace material, and the operational flexibility to handle the unexpected which this method affords.

Pneumatic backfilling is a means of transporting dry solid material through a pipeline while suspended in compressed air and placing that solid material into a void, excavated or natural. A preferred stowing arrangement, as shown in Figure 9.4.3-1, will be to mount the stower and material feed equipment on railcars entrained with a material supply car or supply cars and locomotive. While backfilling, the stower car and one supply car may be positioned at the site of backfilling while another supply car is shuttled by the locomotive back and forth to a material feed storage pile. This equipment precludes the use of long pipeline runs and provides the flexibility to move throughout the repository and backfill at several widely scattered locations. Should rail and other manmade materials be removed prior to backfilling, stowing equipment will be mounted on either crawler or steel tire units.

The pneumatic backfilling system shown in Figure 9.4.3-1 will include an air compressor or blower, stower, hydraulic drive unit, electrical power feeder and switchgear, material receiving hopper, and pipeline. An informal survey of various field operations and literature sources of former backfilling applications performed in the 1970s and 1980s show the following:

- The blower size ranged from 110 to 630 kw at sea level, 300 kw being most common, and produced between 1.4 to 2.8 $m^3/s$ air flow, 1.9 $m^3/s$ being most common. Air pressure at the blower ranged from 55 to 100 kPa with a pipeline operating pressure of 28 to 34 kPa. The blower speed varied between 1,600 and 2,300 revolutions per minute (rpm).

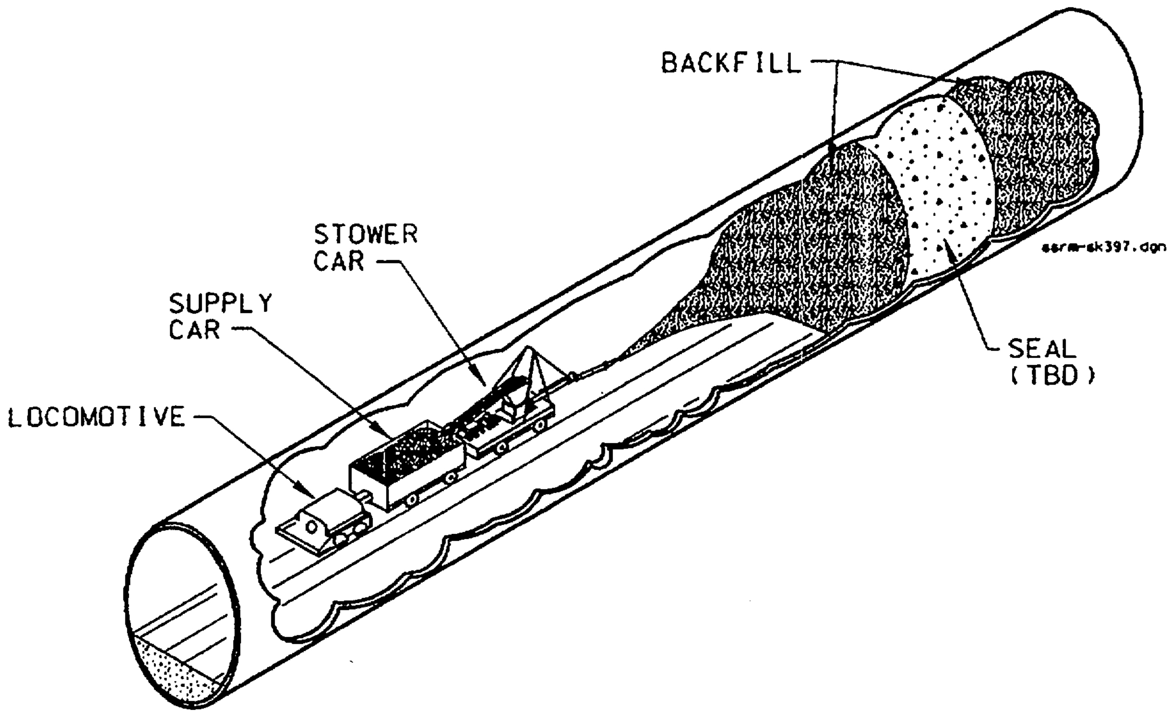


Figure 9.4.3-1. Pneumatic Backfilling at Closure

- Pipelines included both 20.3 and 25.4 cm nominal diameter pipe of schedule 40 and 80 steel construction, rubber-lined light-duty construction, and fiberglass construction were used.

- Piping arrangements included vertical drops of up to 610 m and horizontal runs to 610 m, though plugging problems became excessive in some cases when horizontal pipeline lengths exceeded 370 m.

The central component of the typical industrial pneumatic backfilling system is the stower. The stower is a large rotary air lock that introduces coarse abrasive materials into a fast moving, low pressure airstream. Eight compartments are formed by elongated plates mounted to a central shaft that turns within a curved, tight-fitting case. The bottom of the stower is vertically-elongated, forming an enclosed trough through which compressed air flows. Fill material is dumped into the top open-to-the-air compartment and is carried into the base compartment. The tight fit of the rotor to the casement prevents compressed air from escaping. Once suspended, the material is conveyed through a pipeline connected to the bottom of the stower. Most of the pneumatic backfilling systems surveyed on an industry-wide basis used long pipelines to distribute the material. The mobile system shown in Figure 9.4.3-1 essentially removes the pipeline which is expensive and subject to plugging by using a relatively short pipe to aim the backfill at the point of emplacement. The pipe snout is swiveled and elevated to completely sweep the opening cross-section for complete drift filling.

**9.4.3.2.2 Backfill Stowing Quality Control**

Loose, dry, rocky, or sandy material when stowed pneumatically produces a backfill that may only be partially adequate as an engineered barrier to radionuclide migration. Two conditions can develop including failure to completely fill the drift and settlement of the backfill which can potentially create air gaps along the fill. Pneumatic backfilling tends to produce piles with steeply sloping sides. The material is shot from the end of the pipeline at high speed and impacts causing some compaction which tends to produce a higher internal angle of friction than would be produced by a dumping application. The material accumulates along the line of the trajectory from the end of the pipeline to the point of surface contact with little lateral dispersion. Unless the point of discharge is aimed upward or aimed from side to side, the backfill material will not pile evenly to the top of and across the drift. Pneumatic backfilling generally does not completely fill an underground void during regular mining operations because insufficient time is usually allotted to fill, shut down for examination, reposition the discharge nozzle, and start up several times until the void is completely filled. Severe dusting during pneumatic backfilling obscures vision and precludes continuous monitoring of the stowing activity. In spite of the difficulties, very little void space remains if care is taken to shut down and reposition the discharge nozzle.

The general backfill is expected to settle naturally over a period of time after emplacement, which can be greater after the occurrence of one or more seismic events at the repository site. It has been suggested that settlement will be less than 10 percent of the total height (SNL 1994).

### 9.4.4 Shaft and Ramp Seals

Shaft and ramp seal design has been delayed due to incomplete information concerning site characterization and the performance of possible seal components. Backfill will be emplaced on both sides of each shaft and ramp seal as assumed by the MGDS Concept of Operations in the CDA. Figure 9.4.3-1 shows that pneumatic stowing will be used to emplace the backfill which brackets the seals and fills the main drifts. The backfilling that accomplishes these functions and the potential backfill which may fill the emplacement drifts (if required) may need varying compositions and behaviors when further study is completed. The dumping method of backfilling discussed in Section 8.8 and the pneumatic method of backfilling discussed in Section 9.4.3.2 may be supplemented by a third, undesignated method that provides a backfill-to-seal interface that may not be available with application of the other two methods. Without a further definition of what sealing is to accomplish, seal design cannot be developed beyond the most preliminary stages.

The backfill described in the above subsections of Section 9.4 relates to bulk fill which is applied at a high rate to reduce the emplacement time, achieves low compaction, and has fair to moderate contact with the surrounding rock. Drift seals may require direct contact with a backfill which meets a higher level of quality than may be provided by bulk filling techniques. Principal uncertainties concerning seals include the method of seal construction, composition of seal materials, nature of the interface between the backfill and seal, and characteristics of the backfill.

Following a literature search and number of field visits, Sandia National Laboratories compiled a number of applicable seal geometries that may be applicable to the repository (SNL 1994). The terms "bulkheads," "plugs," and "seals" are used synonymously by Sandia and will be also used in this report. The seals included inundation plugs, hydraulic fill containment bulkheads, abandonment bulkheads, and consolidation plugs and are briefly described as follows:

- Inundation plugs may be installed in shafts, ramps, or drifts to protect from sudden inflows of water. Inundation plugs must often withstand very large pressures and are usually designed for full hydrostatic head to the water table at the site of the operation.

- Hydraulic fill bulkheads are used to retain backfills that having been stowed as a slurry, are held in place during drainage or decanting of the water until the moist backfill has consolidated.

- Abandonment bulkheads are installed to seal off abandoned underground excavations to minimize pumping and/or ventilation requirements. Such bulkheads are designed to withstand hydrostatic pressure in wet conditions and are designed to be explosion-proof in gassy conditions.

- Consolidation bulkheads are used to provide a protection barrier behind which grout curtains can be installed. Consolidation bulkheads may be constructed in a shaft to provide a stable platform upon which inclined, vertical grout holes may be drilled or constructed at a drift heading to maintain the structural integrity of the rock face during grouting through inclined, horizontal drill holes. Such bulkheads are designed to withstand specific hydrostatic limits.

- Conversion bulkheads have been identified for use where an underground excavation has been adopted for gas storage. The construction of the seal includes multiple components incorporated into a complex geometry for minimizing leakage. The case studies found by Sandia also included an oil-filled annulus.

Clearly, some of the seal types given above may not be adequate for repository application on the basis of gaseous or liquid permeability. Variations of the inundation plug and conversion bulkhead may be the most applicable for sealing the repository if permeability becomes an issue due to their higher likelihood of providing impermeable seals.

Basic seal shapes for any application are parallel-sided, arched, or tapered. Parallel seals may be optionally keyed into the surrounding rock, while arched and tapered seals are inherently keyed. The preparation of a keyway will require an over-excavated section at a typical shaft or ramp seal location. Preparation of a keyway requires more preparation and materials than unkeyed seals. Various rock-connected and nonrock-connected construction options are available as shown in Figure 9.4.4-1. As shown in Part a) seals of single composition are keyed into the rock in different arrangements which are designed to couple the seal with the host rock to resist leakage. While leakage may occur through the seal, along the interface between seal and host rock, or through the host rock only, the seal geometries in Part a) of Figure 9.4.4-1 are used when potential leakage through these three pathways is reduced to insignificance. More elaborate seal construction as shown in Part b) of Figure 9.4.4-1 may be used in nonrock-connected situations. Single component seals may be installed as shown in Figure 9.4.4-1 or in multiple component seals as shown in Figure 9.4.4-2.

The seal shown in Figure 9.4.4-2 is a typical nonrock-connected structure in which multiple components interact with fluid intrusion along the seal and host rock interface to minimize leakage. For such seals, specific components are selected for their capability to interact with other components, the intruding fluid, and the host rock.

The development of seal design will likely concentrate on the behavior of potential seal materials and the host rock and the ability to emplace these seals to meet future requirements.

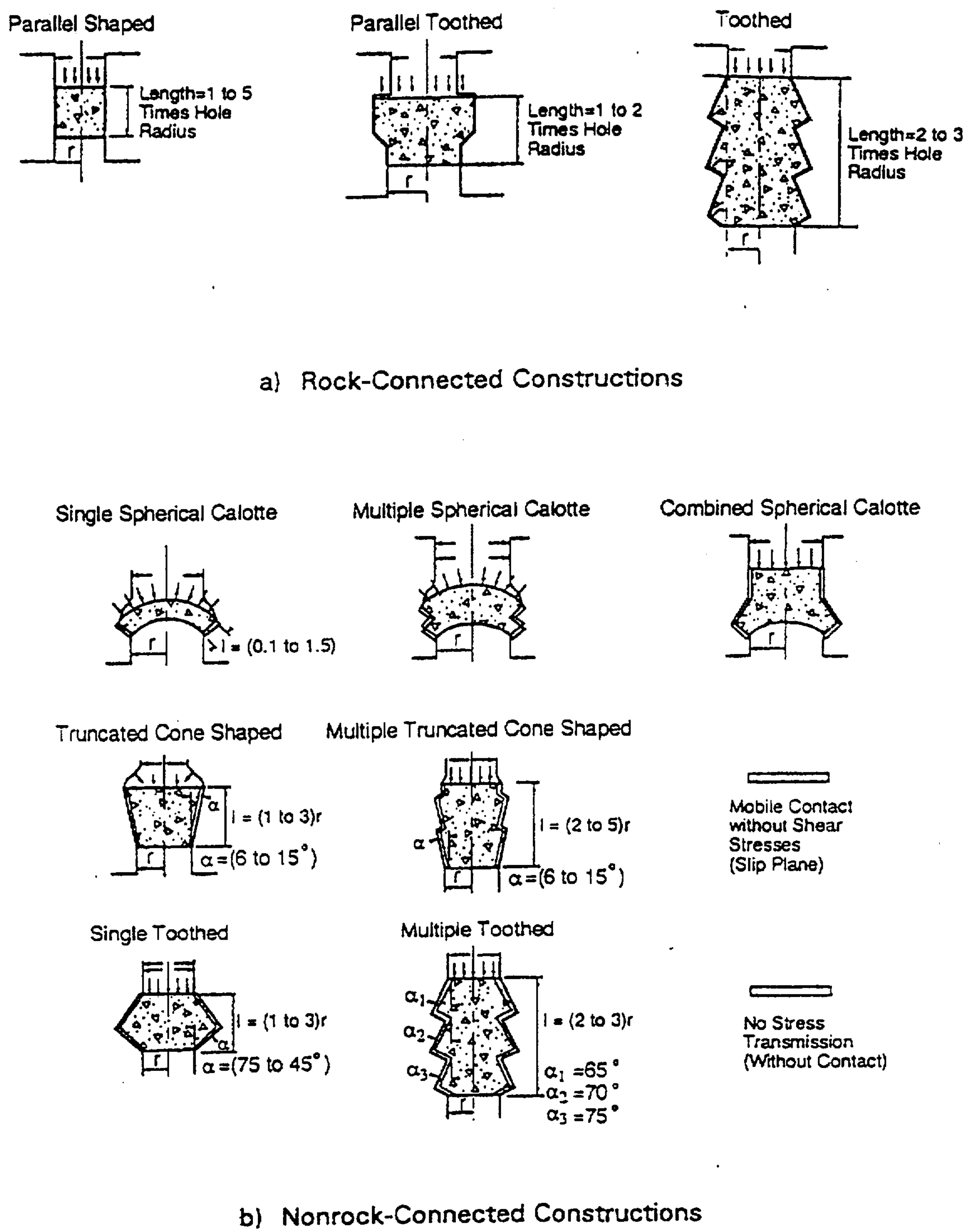


Figure 9.4.4-1. Seal Geometry Alternatives

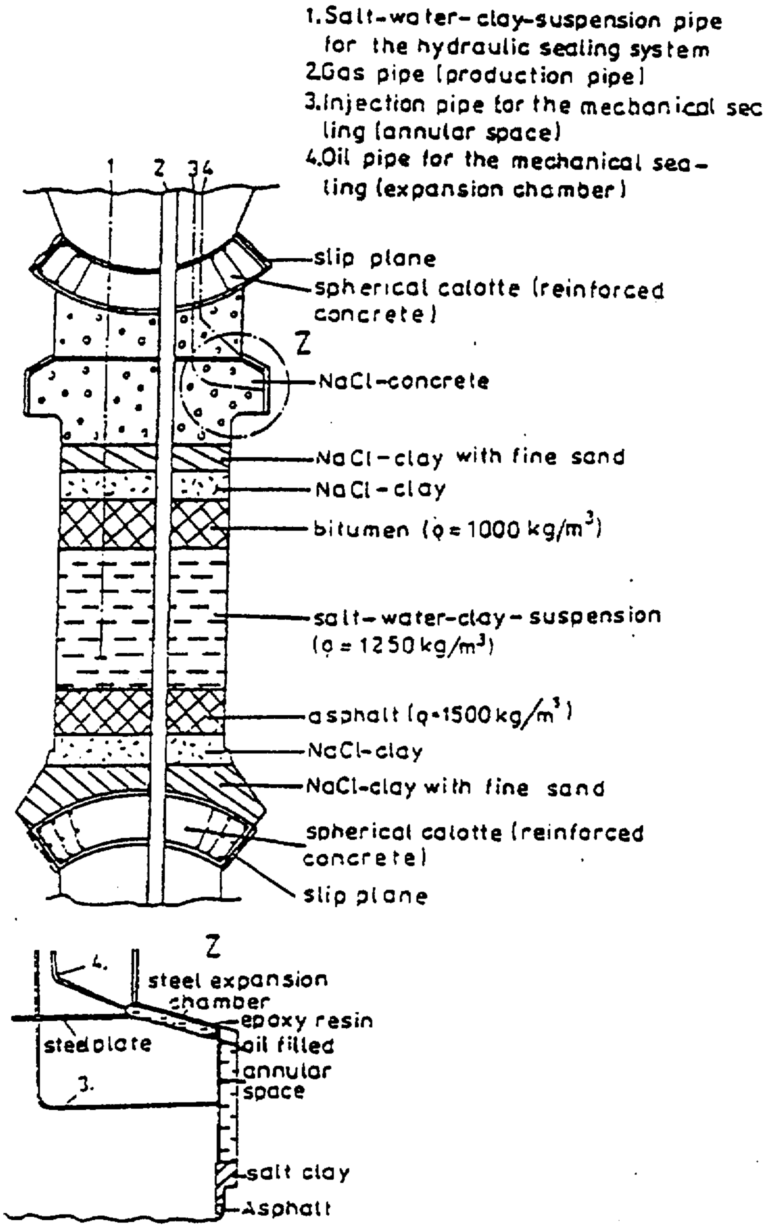


Figure 9.4.4-2. Typical Composite Seal Structure

# 10. SAFETY DESIGN

## 10.1 PRELIMINARY DESIGN BASIS EVENT HAZARDS ANALYSIS

### 10.1.1 Introduction

#### 10.1.1.1 Purpose

This section identifies a list of possible hazards associated with the repository advanced conceptual design (ACD) and provides a preliminary qualitative analysis of the related radiological safety risks. It also documents a process by which the list of hazards is screened to define a list of credible, limiting Design Basis Events (DBEs). The DBE list defines the scope of future detailed quantitative DBE analyses. A preliminary assessment of the repository ACD capability to withstand DBEs is also provided.

Although the level of detail of this section is necessarily different from that of the *Waste Package Off-Normal and Accident Scenario Report* (CRWMS M&O 1996c), the *Preliminary MGDS ACD System Safety Analysis* (CRWMS M&O 1996b), and the two specific analyses (rockfall and criticality) in Volume III, Section 7, of this report, all share the same Preliminary Hazards Analysis, Preliminary Hazards Lists, event screening criteria, and basic assumptions. For this reason, this section and Volume III, Section 7, have been integrated and coordinated with (CRWMS M&O 1996c) as its development proceeds in parallel with the development of this report.

#### 10.1.1.2 Background

This analysis builds on safety assessments done prior to the ACD phase of the design. In particular, lists of potential hazards in two previously issued documents, (SNL 1992) and (SNL 1987), have been used as the starting point for this analysis.

#### 10.1.1.3 Design Methodology

Overall DBE analysis methodology begins with a Preliminary Hazard Analysis of all initiating events identified as applicable to the preclosure phase of the Mined Geologic Disposal System Advanced Conceptual Design (MGDS ACD). This analysis is qualitative in nature and is intended to be inclusive and to characterize at a high level the hazards associated with the repository.

The hazards identified in the Preliminary Hazard Analysis are then screened to filter out all events that are not credible or not limiting or not radiological safety hazards (not capable of causing a radioactive release). The remaining events are defined as preliminary DBEs for the MGDS ACD.

#### 10.1.1.4 Design Status

Safety analysis is an ongoing process throughout all design phases of this project. In the ACD phase, this preliminary DBE hazards analysis has developed a list of DBEs applicable to the repository ACD design. Future safety analysis work will subject each individual DBE on this list to a detailed quantitative DBE analysis.

These DBE analyses will verify the validity of the event as a DBE or document the fact that it no longer warrants consideration as a DBE. Each analysis also will determine what (if any) important to radiological safety (IRS) structures, systems, and components (SSCs) must be credited by design to prevent or mitigate the DBE so that resultant doses to the public and to the worker clearly are less than the limits stated in 10 CFR 20 and 10 CFR 60.

### 10.1.2 Design Inputs

#### 10.1.2.1 Design Requirements

The primary U.S. Nuclear Regulatory Commission (NRC) nuclear safety requirements applicable to the repository ACD include 10 CFR 20 and 10 CFR 60. Overlap and duplication between these requirements and U.S. Department of Energy (DOE) nuclear safety requirements has been avoided through issuance of DOE Order HQ 1321.1 (DOE 1995). This Order exempts CRWMS from DOE nuclear safety requirements that overlap or duplicate NRC requirements with the intent that NRC requirements are the only nuclear safety requirements applicable to the program.

The *Repository Design Requirements Document* (RDRD) (YMP 1994a) is the only design requirements document currently applicable to the repository ACD. Requirements for evaluation of DBEs, as stated in the RDRD, are noted as follows, even though most of them apply to the results of detailed quantitative DBE analyses, which are future work:

| <u>Section</u> | <u>Document Title/Text</u> |
|---|---|
| 3.1.5 | MAJOR CONSIDERATIONS AND ASSUMPTIONS |
| A. | For activities and facilities for which the NRC has regulatory authority, the NRC requirements are the controlling "nuclear safety" requirements. This means that portions of DOE CFR requirements and DOE Orders that address topics covered by CFR requirements issued by the NRC are not applicable to the CRWMS. Specifically, there are no nuclear safety design-related requirements in DOE Order 5480.11 applicable to the RDRD. |
| 3.2.4.6 | DESIGN BASIS EVENTS AND ACCIDENTS |
| A. | Accidents. SSCs that are required to function during accidents shall be designed to withstand accident conditions so that their required functions and performance criteria can be met during such events. |
| B. | Design Objective. Conservatively estimated consequences of normal operations and credible accidents shall be limited in accordance with requirements contained in DOE Order 6430.1A, Section 1300-1.4, *Guidance on Limiting* |

*Exposure of the Public.* [This section will develop events based on site function and licensing requirements. In accordance with the requirement of Section 3.1.5.A above, where there is NRC guidance on the subject, it will be used.]

C. Aircraft. Unless the safety analysis can demonstrate that the risk from an aircraft crashing into the facility is acceptable, potential aircraft crashes shall be considered among the spectrum of man-made missiles that confinement structures must be designed to withstand or against which they must be protected.

D. External Blasts and Missiles. The potential effects of a major explosion at a nearby facility or transportation route shall be considered among the spectrum of external blast effects and missiles that confinement structures must be designed to withstand or against which they must be protected.

E. Internal Blasts and Missiles. The probable consequence of DBEs involving internally generated missiles or blast effects shall be considered. Such DBEs typically involve failure of high-speed rotating machinery, cranes, experimental facilities, high-energy fluid system components, or explosives. Structures required to function following such accidents must be designed to withstand these DBEs.

#### 10.1.2.2 Design Assumptions

Assumptions relevant to evaluation of DBEs are stated in the *Controlled Design Assumptions Document* (CDA) (CRWMS M&O 1995a), which refers to the *Reference Information Base* (RIB) (YMP 1995a) and the *Engineered Barrier Design Requirements Document* (EBDRD) (YMP 1994c). These assumptions are noted as follows, even though most of them apply to detailed quantitative DBE analyses, which are future work:

**Assumption Identifier:** EBDRD 3.2.4.6.A
**Subject:** EBS Design Objective

**I. STATEMENT OF ASSUMPTION**

A. An EBS design objective shall be to ensure that conservatively estimated consequences of normal operations and credible accidents are limited in accordance with requirements contained in DOE Order 6430.1A, Section 1300-1.4, Guidance on Limiting Exposure of the Public. (DOE 1995) exempts the CRWMS from the requirements of DOE Order 6430.1A, citing NRC requirements (primarily 10 CFR 20, -60, and -72) as the only nuclear safety requirements applicable to the program.

**Assumption Identifier:** TDS 006
**Subject:** Design Basis Tornadoes

I. STATEMENT OF ASSUMPTION

The Design Basis Tornado will be based on the "Parameters of Design-Basis Tornadoes for NTS [Nevada Test Site]," which is given in the *Reference Information Base* (YMP 1995a), Section 1.3b, Table 2. Even though tornadoes have never been observed on the NTS or within 150 miles of the NTS, the surface facilities design will be consistent with that used at the NTS.

**Assumption Identifier:** TDS 007
**Subject:** Winds (Operating Basis and Standard)

I. STATEMENT OF ASSUMPTION

The prevailing wind summary given in the *Reference Information Base* (YMP 1995a), Section 1.3a, Table 4, will be used as the Operating Basis Wind and Standard Wind for surface facilities design considerations.

**Assumption Identifier:** TDS 008
**Subject:** Floods (Design Basis)

I. STATEMENT OF ASSUMPTION

The Design Basis Flood shall be the 100-year and 500-year Probable Maximum Floods described in Section 1.54a of the *Reference Information Base* (YMP 1995a); Table 3 identifies the estimated ranges for peak flood characteristics.

**Assumption Identifier:** TDSS 022 **Subject:** Wind Intensity

I. STATEMENT OF ASSUMPTION

Wind intensity:
  Annual Average: 3.22 m/s
  Peak: >26.8 m/s

In addition, the *Reference Information Base* (YMP 1995a), Section 1.3b, Table 1, "Estimated Maximum High Winds at NTS," provides upper limits on wind intensities versus return frequency. For a return frequency of 100 years, the maximum wind intensity is 36.7 m per second with maximum gusts of 47.8 m per second.

### 10.1.2.3 Design Data

Facility design, concepts of operations, and operating basis data, including hazardous material inventories, used as a basis for this analysis are taken from the CDA Document, the RIB, and the RDRD. These data are described or referenced in other sections of this report.

### 10.1.3 Preliminary Hazards Analysis

#### 10.1.3.1 Analysis Methodology

(SNL 1992) and (SNL 1987) identified lists of potential hazards applicable to previous versions of the repository design. These lists have been assessed for applicability to the repository ACD, modified as appropriate, and compiled into Preliminary Hazards Lists, Surface and Subsurface, in (CRWMS M&O 1996a).

A further modified list of the hazards identified in (CRWMS M&O 1996a) is analyzed qualitatively to estimate the degree of safety risk (radiological and non-radiological) associated with each. First, the (CRWMS M&O 1996a) event list is modified by a simple pre-screening. Two sets of events identified in (CRWMS M&O 1996a) are eliminated in accordance with two criteria noted in (CRWMS M&O 1996a):

- Events that are not applicable to the Yucca Mountain site
- Events that are not applicable to the preclosure phase of a repository at the Yucca Mountain site.

The events that are eliminated in this manner are listed in the Notes for Table 10.1-1. All other events identified in (CRWMS M&O 1996a) are evaluated for potential radiological releases in this section. Additionally, events occurring between carrier arrival at the site boundary and carrier arrival at the cask staging shed (impact limiters in place) are considered to be bounded by transport DBEs and are excluded from this analysis.

In (CRWMS M&O 1996a), hazards are classified into the following eight categories:

- Collision/crushing (Hazard Category 1)
- Contamination (H. C. 2)
- Explosion/Implosion (H. C. 3)
- Fire (H.C. 4)
- Radiation/Magnetic (H.C. 5)
- Thermal (H.C. 6)
- Personnel error (all such events lead to hazards described in one or more of the above categories) (H.C. 7)
- Natural phenomena and other external events (H.C. 8)

These categories are used for convenience (i.e., sorting) as the basis for arranging and numbering the events in Table 10.1-1. Under each category, (CRWMS M&O 1996a) lists several types of potential initiating events. For example, in the first category above, (CRWMS M&O 1996a) lists:

- Horizontal drops (Drops where the orientation of the long axis of the dropped item starts and remains in a horizontal direction)
- Vertical drops (Drops where the orientation of the long axis of the dropped item starts and remains in the vertical direction)
- Slapdowns (Drops where the orientation of the long axis of the dropped item rotates from the vertical (or nearly vertical) direction to a horizontal direction, where one end of the item "slaps down" onto the floor or another item)

Each applicable type is represented in Table 10.1-1 for all categories listed in (CRWMS M&O 1996a).

One specific additional type of event has been added to this list. "Non-mechanistic failure" of a waste package is added to allow for safety analysis of repository facilities in parallel with (prior to completion of) the design of the waste package. "Non-mechanistic failure," as used here, is intended to mean a failure of conservatively estimated consequence that is assumed to occur, even though there may be no known credible mechanism that causes the failure.

When the design of the waste package is completed, it is expected to show that the waste package will withstand all DBEs without failure. The non-mechanistic failure event will be used to analyze the response of the repository to a bounding assumed failure of the waste package. The analysis of this assumed failure is expected to show that the repository would mitigate the consequences of such a failure adequately.

Each hazard in the above categories is considered in the context of the operational processes and design features of the repository ACD to develop the following radiological safety risk characteristics:

- Specific mechanisms of occurrence
- Causes
- Inventories of radioactive material at risk

Table 10.1-1. MGDS ACD Preliminary Initiating Event List

| Event No.[B] | Potential Hazard | Cause(s)[C] | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| Note: This table is a summary of preliminary work to date - Some specific conclusions will change as detailed analyses are developed and as the design matures. The overall design requirement (i.e., design in accordance with radiological safety limits) clearly will not change. A,B,C,D,E,F,G See notes at end of table | | | | | | |
| | | | **SURFACE FACILITIES** | | | |
| **INTERNAL EVENTS** | | | | | | |
| 1.1.1 | Shipping Cask drop in Waste Handling Building (WHB) (horizontal) (impact limiters removed, lid bolted on) | Equipment failure (EF)/ Human error (HE) | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to WHB[E] | Contents of 1 Shipping Cask | Neglig. | 2 |
| 1.1.2 | Shipping Cask drop in Cask Maintenance Facility (CMF) (horizontal) (impact limiters removed, lid bolted on) | EF/HE | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to CMF[E] | Contents of 1 Shipping Cask | Neglig. | 2 |
| 1.2.1 | Shipping Cask drop in WHB (vertical) (impact limiters removed, lid bolted on) | EF/HE | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to WHB[E] | Contents of 1 Shipping Cask | Neglig. | 2 |
| 1.2.2 | Shipping Cask drop in CMF (vertical) (impact limiters removed, lid bolted on) | EF/HE | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to CMF[E] | Contents of 1 Shipping Cask | Neglig. | 2 |
| 1.3 | SFC drop (vertical - not onto DC) | EF/HE | SFC failure/Up to 21 PWR or 40 BWR SFAs damaged/release to WHB | Contents of 1 SFC | Major | 1 |
| 1.4 | SFA drop (vertical - not onto DC, but possibly onto another SFA) | EF/HE | 1 or 2 SFA(s) damaged/release to WHB | 1 or 2 SFAs | Moderate | 2 |
| 1.5 | HLWC drop (vertical - not onto DC, but possibly onto another HLWC) | EF/HE | 1 or 2 HLWC(s) damaged/possible negligible release to WHB | 1 or 2 HLWCs | Neglig. | 1 |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 1.6 | WP drop (vertical) | EF/HE | Neglig.[D] | | Neglig. | 1 |
| 1.7 | WP drop (horizontal) | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.8 | Shipping cask slapdown (impact limiters removed, lid removed) | EF/HE, Seismic (See 8.1 below) | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to WHB[E] | Contents of 1 Shipping Cask | Neglig. to Major | 2 |
| 1.9 | SFC slapdown | EF/HE, Seismic (See Event 8.1 below) | SFC damage or failure/ Possible damage to up to 21 PWR or 40 BWR SFAs/Possible release to WHB | Contents of 1 SFC | Moderate to Major | 1 |
| 1.10 | HLWC slapdown | EF/HE, Seismic (See Event 8.1 below) | HLWC damage or failure/ Possible release to WHB | 1 HLWC | Neglig. | 1 |
| 1.11 | WP slapdown | EF/HE, Seismic (See Event 8.1 below) | WP[C] | 1 WP | Neglig. | 2 |
| 1.12 | SFA drop onto sharp object | EF/HE | Damage to SFA/release to WHB | 1 SFA | Moderate | 2 |
| 1.13 | WP drop onto sharp object | EF/HE | Damage to WP/release to WHB | 1 WP | Neglig. To Major | 2 |
| 1.14 | Cask collision (impact limiters removed, lid removed) | EF/HE | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to WHB[E] | Contents of 1 Shipping Cask | Neglig. to Major | 2 |
| 1.15 | SFC collision | EF/HE | Possible SFC damage or failure/ Possible damage to up to 21 PWR or 40 BWR SFAs/Possible release to WHB | Contents of 1 SFC | Moderate to Major | 1 |
| 1.16 | SFA collision | EF/HE | Possible SFA damage/Possible release to WHB | 1 SFA | Moderate | 2 |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 1.17 | HLWC collision | EF/HE | Possible HLWC damage or failure/ Possible neglig. release to WHB | 1 HLWC | Neglig. | 1 |
| 1.18 | WP collision | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.19 | Shield door jams shipping cask (impact limiters removed, lid removed) | EF/HE | Possible damage to shipping cask, damage to contents (SFC, HLWC, or up to 21 PWR or 40 BWR SFAs)/release to WHB[E] | Contents of 1 Shipping Cask | Neglig. to Major | NC |
| 1.20 | Shield door jams WP | EF/HE | WP[C] | 1 WP | Neglig. | NC |
| 1.21 | SFC drops onto unsealed DC | EF/HE | SFC failure/Up to 21 PWR or 40 BWR SFAs damaged/release to WHB | Contents of 1 SFC | Major | 1 |
| 1.22 | SFA drops onto DC | EF/HE | 1 or 2 SFA(s) damaged/release to WHB | 1 or 2 SFAs | Moderate | 2 |
| 1.23 | HLWC drops onto DC | EF/HE | 1 or 2 HLWC(s) damaged/possible negligible release to WHB | 1 or 2 HLWCs | Neglig. | 1 |
| 1.24 | Automatic Center of Gravity Lift Fixture (ACGLF) drops onto WP | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 1.25 | Non-mechanistic failure of WP in WHB | Not specified | Release from WP to WHB | 1 WP | Major | 2 (Assum'd) |
| 1.26 | WP car derailment in WHB | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 1.27 | Transporter derailment outdoors | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 1.28 | Transporter derailment outdoors + WP ejected | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 1.29 | Transporter derailment outdoors + WP ejected + Non-mechanistic WP failure outdoors | Not specified | Release from WP to atmosphere | 1 WP | Major | 2 (Assum'd) |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 3.1 | Decon (or other pneumatic or pressurized) system missile - nozzle/ valve stem/pneumatic device | EF | Possible SFC, SFA, or HLWC damage/Possible release to WHB/DC[C] | 1 SFC, 1 SFA, 1 HLWC, or 1 DC | Neglig. | 2 |
| 3.2 | Decon system failure - internal flooding into/around WP | EF | Criticality threat/Possible release to WHB/WP[C] | | | |
| 4.1 | Fire in WHB fuel handling area | Combus-tibles/ Heat source | Possible SFC, SFA, or HLWC damage/Possible release to WHB/ WP[C] (after welding ) | One or more SFCs, SFAs, HLWCs, WPs | Neglig. to Major | 1, 2 |
| 4.2 | Fire in WHB external to fuel handling area | Combus-tibles/ Heat source | No release/Fire barriers will protect fuel handling areas | None | Neglig. | 1, 2 |
| 5.1 | Fuel damage by laser radiation/heat/burnthrough during welding process | EF/HE | Possible SFC, SFA, HLWC or DC damage/ Possible leakage to WHB due to incomplete welds | One DC or SFC, one or more SFAs or HLWCs | Neglig. to Moderate | 1 |
| **EXTERNAL EVENTS** | | | | | | |
| 8.1.a | Seismic activity (earthquakes) | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.1.b | Seismic activity (active faulting, shear zone at the site) | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | NC |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 8.2 | Flooding (storm, river diversion) | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible wetting or submergence of or damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.3 | Lightning | Natural Phenom. | Possible fire or other damage to or collapse of buildings and other structures/ Possible damage to one or more Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.4.1 | Volcanic activity (magmatic activity) | Natural Phenom. | Possible fire damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | NC (Pre-closure) |
| 8.4.2 | Volcanic activity (ashfall) | Natural Phenom. | Possible collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.5 | Weather fluctuations and extremes (snow, hail, ice, temperature extremes) | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 1, 2, NC |
| 8.6 | Chemical effects (release of chemicals on site, e.g., toxic gas) | EF/HE | Personnel injury/No other significant effects/No releases[D] | None | Neglig. (No radio-active releases) | 1, 2, NC |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 8.7 | Sandstorm | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.8 | Tornado | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.9 | Extreme wind | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.10 | Industrial activity accident | EF/HE | Unknown at this time - Possible fire or other damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| 8.11 | Military accident (weapons testing, aircraft impact, bombing) | EF/HE | Possible fire or other damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | NC |
| 8.12 | Crash of commercial aircraft (helicopter, passenger planes, etc.) | EF/HE | Possible fire or other damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | NC |
| 8.14 | Intentional future intrusion | Sabotage, Terrorism | No significant effects | None | Neglig. | 2, NC |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 8.16 | Range fire | Natural Phenom./ HE or sabotage | Possible fire damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 1, 2 |
| 8.18 | Loss of offsite/ onsite (SBO) AC power | EF/HE | Interruption of handling operations & HVAC/No significant effects on radioactive materials/No releases [D] | None | Neglig. | 1, 2, NC |
| 8.41 | Static fracturing (surficial fissuring, impact fracturing, hydraulic fracturing) | Natural Phenom. | Possible damage to or collapse of buildings and other structures/ Possible damage to all Shipping Casks, SFCs, SFAs, HLWCs and WPs/Possible large scale releases/WP[C] | Entire WHB inventory | Neglig. to cata-strophic | 2, NC |
| **SUB-SURFACE FACILITIES** | | | | | | |
| **INTERNAL EVENTS** | | | | | | |
| 1.1 | Transporter derailment in ramp or main drift | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.1.1 | Transporter derailment + WP ejected | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 1.1.2 | Non-mechanistic WP failure in main drift following transporter derailment + WP ejection | Not specified | Release from WP, Contamination of ramp or main drift | 1 WP | Major | 2 (Assum'd) |
| 1.2 | Emplacement rail car derailment | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.2.1 | Non-mechanistic WP failure in main drift following emplacement rail car derailment | Not specified | Release from WP, Contamination of emplacement drift | 1 WP | Major | 2 (Assum'd) |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 1.3 | WP car rolls out of transporter | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.3.1 | Non-mechanistic WP failure following loss or absence of restraint and rollout of WP car from transporter | Not specified | Release from WP, Contamination of ramp or main drift | 1 WP | Major | 2 (Assum'd) |
| 1.4 | Transporter collision w/another transporter | EF/HE | WP[C] | 1 or 2 WPs | Neglig. | 1 |
| 1.5 | Emplacement rail car collision w/emplacement locomotive | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.6 | Runaway transporter | EF/HE | WP[C] | 1 WP | Neglig. | NC |
| 1.7 | Decoupled transporter | EF/HE | None | 1 WP | Neglig. | 1 |
| 1.8 | External unloading mechanism fails | EF/HE | Emplacement rail car rolls out of sloped emplacement drift and falls in to main drift/WP[C] | 1 WP | Neglig. | 1 |
| 1.9 | Transport cask internal off-loading mechanism fails | EF/HE | WP/emplacement rail car stranded halfway out of transporter cask | 1 WP | Neglig. | 1 |
| 1.10 | Transport cask door jams WP | EF/HE | WP/emplacement rail car stranded halfway out of transporter cask/WP[C] | 1 WP | Neglig. | 1 |
| 1.11 | Emplacement drift door jams WP | EF/HE | WP[C] | 1 WP | Neglig. | 1 |
| 1.12 | Rockfall onto transporter | EF/HE (incl. rockbolt failure) | WP[C] | 1 WP | Neglig. | 1 |
| 1.13 | Rockfall onto WP/emplacement rail car | EF/HE (incl. rockbolt failure) | WP[C] | 1 WP | Neglig. | 1 |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 1.14 | Steel set drop onto WP | EF/HE | WP[C] | 1 WP | Neglig. | 2, NC |
| 1.15 | Loss of WP cart restraint in sloped emplacement drift | EF | WP[C] | 1 or 2 WPs | Neglig. | 2 (Assumed) |
| 3.1 | Hydrogen Explosion (from batteries) | EF/HE | WP[C,F] | 1 WP | Neglig. | 2 |
| 3.2 | Dust Explosion (from rubber conveyor belts) | EF/HE | WP[C,F] | 1 WP | Neglig. | 2 |
| 4.1 | Fire | EF/HE | WP[C] | 1 WP | Neglig. | 2 |
| 6.1 | Thermal cycling of WP | Blast cooling for retrieval | WP[C] | 1 WP | Neglig. | 2 |
| EXTERNAL EVENTS | | | | | | |
| 8.1.a | Seismic activity (earthquakes) | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to cata-strophic | 2, NC |
| 8.1.b | Seismic activity (active faulting, shear zone at the site) | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to cata-strophic | NC |
| 8.2 | Flooding (storm, river diversion) | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to cata-strophic | 2, NC |
| 8.3 | Volcanic activity | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to cata-strophic | NC (Pre-closure) |
| 8.14 | Intentional future intrusion | Sabotage, Terrorism | No significant effects | None | Neglig. | 2, NC |

Table 10.1-1. MGDS ACD Preliminary Initiating Event List[A] (continued)

| Event No.[B] | Potential Hazard | Cause(s) | Unmitigated Consequences | Inventory at Risk | Conseq. Category | Frequency Category |
|---|---|---|---|---|---|---|
| 8.18 | Loss of offsite/ onsite (SBO) AC power | EF/HE | Interruption of handling operations & HVAC/No significant effects on radioactive materials/No releases[D] | None | Neglig. | 1, 2, NC |
| 8.35 | Thermal loading | Design Condition | No significant effects | None | Neglig. | 2, NC |
| 8.36 | Geochemical alterations | Natural Phenom. | No significant effects | None | Neglig. | 2, NC |
| 8.37 | Waste and rock interactions | Natural Phenom. | No significant effects | None | Neglig. | 2, NC |
| 8.38 | Rockfall | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to catastrophic | NC |
| 8.41 | Static fracturing (surficial fissuring, impact fracturing, hydraulic fracturing) | Natural Phenom. | Possible damage to or collapse of drifts/ Possible damage to all WPs/Possible large scale releases/WP[C] | All subsurface WPs | Neglig. to catastrophic | 2, NC |

Note A: The following external hazards have not been included in the Preliminary Hazards List because, as noted in (CRWMS M&O 1996a), they do not apply to the Yucca Mountain site:

8.13 Undetected* past intrusion (undiscovered bore holes or mine shafts)
8.17 Pipeline accident (Gas, etc.)
8.20 Avalanche
8.21 Coastal erosion
8.22 High tide, high lake or river level
8.23 Low lake or river level
8.24 Hurricane
8.25 Meteorite
8.26 Seiche
8.27 Tsunami
8.28 Dam failure
8.29 Waves
8.30 Undetected* features and processes (breccia pipes, lava tubes, gas or brine pockets, etc.)
8.31 Sedimentation
8.33 Landslide
8.40 Dissolution

*Undetected intrusions and undetected features and processes are considered to be not applicable to the Yucca Mountain site (CRWMS M&O 1996a).

The following external events have not been included in the Preliminary Hazards List because, as noted in (CRWMS M&O 1996a), they do not apply to preclosure phase of the Yucca Mountain Project:

8.15 Inadvertent future intrusion
8.19 Perturbation of groundwater system
8.32 Subsidence
8.34 Uplifting
8.39 Glaciation
8.42 Denudation and stream erosion
8.43 Magmatic activity (extrusive, intrusive)
8.44 Epeirogenetic displacement
8.45 Orogenic diastrophism

Note B: The numbering system used is the result of sequentially numbering the events identified in (CRWMS M&O 1996a).

Note C: Potential impacts to waste package are described in Vol. III, Section 7.0 of this report and in (CRWMS M&O 1996c). Pending detailed analysis of the waste package response to each event, it is assumed that waste package integrity is maintained in each case. Events 1.23 and 1.27 (surface) and 1.1.2, 1.2.1 and 1.3.1 (subsurface), however, will analyze the consequences of postulated non-mechanistic waste package failures.

Note D: Vol. III, Section 6.0 of this report includes an analysis showing that the maximum vertical drop event will not breach waste package integrity.

Note E: Transportation accidents are assumed to bound these events, as well as shipping cask events occurring between the site boundary and the Waste Handling Building. The shipping cask (lid bolted on) is assumed to withstand each event without breach and without damage to the contents.

Note F: Even if hydrogen or dust explosion were to occur, it would be on a relatively minor scale because of limited fuel supply. Obviously, either would be a significant burn/impact hazard to personnel in the vicinity. It is equally clear, however, that the threat of a radiological release caused by the explosion would be insignificant. There would be no significant effect on a transporter (mass in excess of 100 tonnes) or even a WP (mass of approximately 50 tonnes), both of which will be extremely robust structures. For example, neither derailment nor breach of containment is considered a credible outcome of such an explosion.

Note G: External events such as Loss of Offsite Power/Station Blackout and Toxic Gas Release are included as DBEs even though no radioactive release is expected to result. The NRC has required in the past (for nuclear power plant (NPP) applicants) that these events be analyzed because of the high decay heat rates present in NPPs. Active mitigation is required quickly to prevent such events at a NPP from causing a radioactive release.

For the MGDS, standard design of nuclear fuel handling equipment (e.g., cranes that stop movement and apply brakes on loss of power) should make such a release not credible. It is expected, however, that the NRC will expect this to be proven in the form of a documented DBE analysis.

- Consequence Category: Unmitigated consequences, in the following broad qualitative categories of severity:

  - Negligible: No significant radiological release.

  - Moderate: Release in the range of that caused by damage to a single spent fuel assembly (SFA)

  - Major: Release in the range of that caused by damage to a single spent fuel canister (SFC), which can hold up to 21 PWR/40 BWR SFAs each

  - Catastrophic: Release in the range of that caused by a severe earthquake (collapse of buildings), involving from several SFCs up to the entire inventory of the surface facilities

- Frequency Category: Frequency of occurrence of the initiating event (in the following broad categories). The following qualitative definitions of "frequency categories" are used in this section and the accompanying tables:

  - Frequency Category 1:
    Those initiating events that are reasonably likely to occur regularly, moderately frequently, or one or more times before permanent closure of the geologic repository operations area

  - Frequency Category 2:
    Other initiating events that are considered unlikely, but sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on the health and safety of the public

  - Frequency Category NC:
    Those initiating events that are considered to be not credible during the preclosure phase

These definitions of frequency categories are in accordance with current requirements listed in Section 10.1.2.1. They also are consistent with the recently proposed changes to 10 CFR 60.

In addition to the hazards analysis, a further DBE screening process is documented in Table 10.1-2. This process answers the following questions to determine whether each event in Table 10.1-1 should be evaluated further as a potential DBE (all questions should be answered "Yes" for the event to become a DBE):

- Is the initiating event credible? An event is considered credible unless its estimated frequency of occurrence is clearly below the threshold of credibility, in which case it is considered to be not credible, or beyond the design basis. The basic threshold of credibility for both the NRC and the DOE is $1x10^{-6}$/yr (or one event every one million years).

Table 10.1-2. MGDS ACD Design Basis Event Screening Process

| Event Type | Event No. | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| | | | | **SURFACE FACILITIES** | | | | |
| **INTERNAL EVENTS** | | | | | | | | |
| Shipping Cask Drop in WHB | 1.1.1 | Shipping Cask drop in WHB (horizontal) (impact limiters removed, lid bolted on) | 2 | Yes | No | No (See 1.8) | No | No |
| Shipping Cask Drop in CMF | 1.1.2 | Shipping Cask drop in CMF (horizontal) (impact limiters removed, lid bolted on) | 2 | Yes | No | No (None) | No | No |
| Shipping Cask Drop in WHB | 1.2.1 | Shipping Cask drop in WHB (vertical) (impact limiters removed, lid bolted on) | 2 | Yes | No | No (See 1.8) | No | No |
| Shipping Cask Drop in CMF | 1.2.2 | Shipping Cask drop in CMF (vertical) (impact limiters removed, lid bolted on) | 2 | Yes | No | No (None) | No | No |
| SFC Drop | 1.3 | SFC drop (vertical - not onto DC) | 1 | Yes | Yes | Yes | Yes (1) | No |
| SFA Drop | 1.4 | SFA drop (vertical - not onto DC, but possibly onto another SFA) | 2 | Yes | Yes | Yes | Yes (2) | No |
| HLWC Drop | 1.5 | HLWC drop (vertical - not onto DC, but possibly onto another HLWC) | 1 | Yes | Yes | Yes | Yes (3) | No |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| Type | No. | | | | | | | |
| WP Drop | 1.6 | WP drop (vertical) | 2 | Yes | Yes | No (See 1.11) | No | No |
| WP Drop | 1.7 | WP drop (horizontal) | 2 | Yes | Yes | No (See 1.11) | No | No |
| Shipping Cask Drop in WHB | 1.8 | Shipping cask slapdown (impact limiters removed, lid removed) | 2 | Yes | Yes | Yes | Yes (4) | No |
| SFC Drop | 1.9 | SFC slapdown | 1 | Yes | Yes | No (See 1.3) | No | No |
| HLWC Drop | 1.10 | HLWC slapdown | 1 | Yes | Yes | No (See 1.5) | No | No |
| WP Drop | 1.11 | WP slapdown | 2 | Yes | Yes | Yes | Yes (5) | No |
| SFA Drop onto Sharp Object | 1.12 | SFA drop onto sharp object | 2 | Yes | Yes | Yes | Yes (6) | No |
| WP Drop onto Sharp Object | 1.13 | WP drop onto sharp object | 2 | Yes | Yes | Yes | Yes (7) | No |
| Shipping Cask Drop in WHB | 1.14 | Cask collision (impact limiters removed, lid bolted on) | 2 | Yes | Yes | No (See 1.8) | No | No |
| SFC Drop | 1.15 | SFC collision | 1 | Yes | Yes | No (See 1.3) | No | No |
| SFA Drop | 1.16 | SFA collision | 2 | Yes | Yes | No (See 1.4) | No | No |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type | No. | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
| HLWC Drop | 1.17 | HLWC collision | 1 | Yes | Yes | No (See 1.5) | No | No |
| WP Drop | 1.18 | WP collision | 1 | Yes | Yes | No (See 1.11) | No | No |
| Shipping Cask Drop in WHB | 1.19 | Shield door jams shipping cask (impact limiters removed, lid bolted on) | NC | No | Yes | No (See 1.8) | No | No |
| WP Drop | 1.20 | Shield door jams WP | NC | No | Yes | No (See 1.11) | No | No |
| Waste Form Drop Onto DC | 1.21 | SFC drops onto unsealed DC | 1 | Yes | Yes | Yes | Yes (8) | No |
| Waste Form Drop Onto DC | 1.22 | SFA drops onto DC | 2 | Yes | Yes | No (See 1.21) | No | No |
| Waste Form Drop Onto DC | 1.23 | HLWC drops onto DC | 1 | Yes | Yes | No (See 1.21) | No | No |
| Equipment Drop onto WP | 1.24 | Automatic Center of Gravity Lift Fixture (ACGLF) Drop onto WP | 2 | Yes | Yes | Yes | Yes (9) | No |
| WP Failure | 1.25 | Non-mechanistic failure of WP in WHB | 2 (Assumed) | Yes | Yes | Yes | Yes (10) | No |
| WP Drop | 1.26 | WP cart derailment in WHB | 2 | Yes | No | No (See 1.11) | No | No |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| Type | No. | | | | | | | |
| WP Drop | 1.27 | Transporter derailment/ collision outdoors | 2 | Yes | No | No (See 1.11) | No | No |
| WP Drop | 1.28 | Transporter derailment/ collision outdoors + WP ejected | 2 | Yes | No | No (See 1.11) | No | No |
| WP Failure Outdoors | 1.29 | Transporter derailment/ collision outdoors + WP ejected + Non-mechanistic WP failure | 2 (Assumed) | Yes | Yes | Yes | Yes (11) | No |
| Equipment Drop Onto WP | 3.1 | Decon system missile - nozzle/valve stem/pneumatic device | 2 | Yes | No | No (See 1.24) | No | No |
| Internal Flooding | 3.2 | Decon system failure - internal flooding into/around WP (criticality threat) | 2 | Yes | Yes | Yes | Yes (12) | No |
| Fire | 4.1 | Fire in WHB fuel handling area | 1, 2 | Yes | Yes | Yes | No (Deferred to Fire Hazards Analysis) | No |
| Fire | 4.2 | Fire in WHB external to fuel handling area | 1, 2 | Yes | No | No | No (Deferred to Fire Hazards Analysis) | No |
| Fuel Damage by Laser/ Welding Process | 5.1 | Fuel damage by laser radiation/heat/ burnthrough during welding process | 1 | Yes | Yes | Yes | Yes (13) | No |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type** | **No.** | **Potential Hazard** | **Frequency Category** | **Credible?** | **Causes A Release?** | **Limiting Conseq. in Type?** | **DBE? If Yes: (DBE #)** | **Beyond DBE? (Residual Risk)** |
| **EXTERNAL EVENTS** | | | | | | | | |
| Earthquake | 8.1.a | Seismic activity (earthquakes) | 2, NC | Yes | Yes | Yes | Yes (14) | Yes |
| Active Seismic Faulting | 8.1.b | Seismic activity (active faulting, shear zones at the site) | NC | No | Yes | Yes | No | Yes |
| Flood | 8.2 | Flooding (storm, river diversion) | 2, NC | Yes | Yes | Yes | Yes (15) | Yes |
| Lightning | 8.3 | Lightning | 2, NC | Yes | Yes | Yes | Yes (16) | Yes |
| Volcanic Activity | 8.4.1 | Volcanic activity (magmatic activity) | NC (Preclosure) | No | Yes | Yes | No | Yes |
| Volcanic Activity | 8.4.2 | Volcanic activity (ashfall) | 2, NC | Yes | Yes | Yes | Yes (17) | Yes |
| Weather | 8.5 | Weather fluctuations and extremes (snow, hail, ice, temperature extremes) | 1, 2, NC | Yes | No | No (None) | No (Normal conditions, not considered initiating events, but as initial conditions in DBE analysis) | Yes |
| Toxic Gas | 8.6 | Chemical effects (release of chemicals on site, e.g., toxic gas) | 1, 2, NC | Yes | No[G] | Yes | Yes (18) | Yes |
| Sandstorm | 8.7 | Sandstorm | 2, NC | Yes | Yes | Yes | Yes (19) | Yes |
| Tornado | 8.8 | Tornado | 2, NC | Yes | Yes | Yes | Yes (20) | Yes |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| Type | No. | | | | | | | |
| Wind | 8.9 | Extreme wind | 2, NC | Yes | Yes | Yes | Yes (21) | Yes |
| Industrial Accident | 8.10 | Industrial activity accident | 2, NC | Yes | Yes | Yes | Yes (22) | Yes |
| Aircraft Crash | 8.11 | Military accident (weapons testing, aircraft impact, bombing) | NC | No | Yes | Yes | No | Yes |
| Aircraft Crash | 8.12 | Crash of commercial aircraft (helicopter, passenger planes, etc.) | NC | No | Yes | No (See 8.11) | No | Yes |
| Safeguards & Security | 8.14 | Intentional future intrusion | 2, NC | Yes | Yes | Yes | Yes (23) | Yes |
| External Fire | 8.16 | Range fire | 1, 2 | Yes | Yes | Yes | No (Deferred to Fire Hazards Analysis) | No |
| Loss of Power | 8.18 | Loss of offsite/ onsite(SBO) AC power | 1, 2, NC | Yes | No[G] | Yes | Yes (24) | Yes |
| Geolog. Fracturing | 8.41 | Static fracturing (surficial fissuring, impact fracturing, hydraulic fracturing) | 2, NC | Yes | Yes | Yes | Yes (25) | Yes |
| **SUB-SURFACE FACILITIES** | | | | | | | | |
| **INTERNAL EVENTS** | | | | | | | | |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| Type | No. | | | | | | | |
| WP Drop | 1.1 | Transporter derailment in ramp or main drift | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.1.1 | Transporter derailment + WP ejected | 2 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Failure in Drift | 1.1.2 | Non-mechanistic WP failure in main drift following transporter derailment + WP ejection | 2 (Assumed) | Yes | Yes | Yes | Yes (1) | No |
| WP Drop | 1.2 | Emplacement rail car derailment | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Failure in Drift | 1.2.1 | Non-mechanistic WP failure in main drift following emplacement rail car derailment | 2 (Assumed) | Yes | Yes | Yes | Yes (1) | No |
| WP Drop | 1.3 | WP rolls out of transporter | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Failure in Drift | 1.3.1 | Non-mechanistic WP failure following loss or absence of restraint and rollout of WP car from transporter | 2 (Assumed) | Yes | Yes | Yes | Yes (1) | No |
| WP Drop | 1.4 | Transporter collision w/another transporter | 1 | Yes | No | No (See 1.11 - Surface) | No | No |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type | No. | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. in Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
| WP Drop | 1.5 | Emplacement rail car collision w/emplacement locomotive | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.6 | Runaway transporter | NC | No | Yes | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.7 | Decoupled transporter | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.8 | External unloading mechanism fails | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.9 | Transport cask internal off-loading mechanism fails | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.10 | Transport cask door jams WP | 1 | Yes | No | No (See 1.11 - Surface) | No | No |
| WP Drop | 1.11 | Emplacement drift door jams WP | NC | No | No | No (See 1.11 - Surface) | No | No |
| Rockfall (Internal) | 1.12 | Rockfall onto transporter | 1 | Yes | No | No (None) | No | No |
| Rockfall (Internal) | 1.13 | Rockfall onto WP/emplacement rail car | 1 | Yes | No | No (None) | No | No |
| Equipment Drop onto WP in Drift | 1.14 | Steel set drop onto WP | 2, NC | Yes | Yes | Yes | Yes (2) | Yes |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | Potential Hazard | Frequency Category | Credible? | Causes A Release? | Limiting Conseq. In Type? | DBE? If Yes: (DBE #) | Beyond DBE? (Residual Risk) |
|---|---|---|---|---|---|---|---|---|
| Type | No. | | | | | | | |
| Loss of WP Restraint | 1.15 | Loss of WP cart restraint in sloped emplacement drift | 2 (Assumed) | Yes | Yes | Yes | Yes (3) | No |
| Hydrogen Explosion | 3.1 | Hydrogen Explosion (from batteries) | 2 | Yes | No[F] | Yes | No | No |
| Dust Explosion | 3.2 | Dust Explosion (from rubber conveyor belts) | 2 | Yes | No[F] | Yes | No | No |
| Fire in Drift | 4.1 | Fire | 2 | Yes | Yes | Yes | No (Deferred to Fire Hazards Analysis) | No |
| Thermal Cycling of WP | 6.1 | Thermal cycling of WP due to blast cooling for retrieval | 2 | Yes | Yes | Yes | Yes (4) | No |
| **EXTERNAL EVENTS** | | | | | | | | |
| Earthquake | 8.1.a | Seismic activity (earthquakes) | 2, NC | Yes | Yes | Yes | Yes (5) | Yes |
| Active Seismic Faulting | 8.1.b | Seismic activity (active faulting, shear zones at the site) | NC | No | Yes | Yes | No | Yes |
| Flood | 8.2 | Flooding (storm, river diversion) | 2, NC | Yes | Yes | Yes | Yes (6) | Yes |
| Volcanic Activity | 8.3 | Volcanic activity (magmatic activity) | NC (Preclosure) | No | Yes | Yes | No | Yes |
| S&S | 8.14 | Intentional future intrusion | 2, NC | Yes | Yes | Yes | Yes (7) | Yes |

Table 10.1-2. MGDS ACD Design Basis Event Screening Process (continued)

| Event | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type** | **No.** | **Potential Hazard** | **Frequency Category** | **Credible?** | **Causes A Release?** | **Limiting Conseq. in Type?** | **DBE? If Yes: (DBE #)** | **Beyond DBE? (Residual Risk)** |
| Loss of Power | 8.18 | Loss of offsite/ onsite (SBO) AC power | 1, 2, NC | Yes | No[G] | Yes | Yes (8) | Yes |
| Thermal Loading | 8.35 | Thermal loading | 1 | Yes | No (Normal Design Condition) | Yes | No (Normal Design Condition, Not an Off-Normal Event) | No |
| Geochem. Alterations | 8.36 | Geochemical alterations | 2, NC | Yes | Yes | Yes | Yes (9) | Yes |
| Waste/ Rock Interaction | 8.37 | Waste and rock interactions | 2, NC | Yes | Yes | Yes | Yes (10) | Yes |
| Rockfall | 8.38 | Rockfall | NC | No | Yes | Yes | No | Yes |
| Geolog. Fracturing | 8.41 | Static fracturing (surficial fissuring, impact fracturing, hydraulic fracturing) | 2, NC | Yes | Yes | Yes | Yes (11) | Yes |

- Can the initiating event cause a radioactive release? Some events could involve hazards not capable of causing exposure to radiation. These events are outside the scope of a Design Basis Event analysis.

- Does the initiating event cause the most severe unmitigated consequence in its type? One bounding event in each type is retained as a DBE. Generally, if a design can provide adequate protection against the most severe event in the type, then it can provide adequate protection against all lesser events of the same type. For example, the consequences of an SFA drop or a high-level waste canister (HLWC) drop onto a partially filled disposal container (DC) are bounded by the consequences of an SFC drop onto a partially filled DC: SFC drop is the DBE for the "drop onto DC" type of event. The safety design basis can be defined without expending resources on a detailed analysis of the SFA drop and HLWC drop events.

Table 10.1-2 provides a preliminary basis for exclusion from or inclusion in the remaining list of DBEs. To provide completeness, this table also is used to identify those initiating events which are considered to have elements of residual risk that warrant further consideration. Some events, particularly natural phenomena hazards such as earthquakes, occur across a wide spectrum of severity versus frequency of occurrence. That part of the spectrum with frequencies below the threshold of credibility is identified as "beyond the design basis," which is part of the "residual risk" associated with the design.

Analysis done using the methodology described in this section is performed as a preliminary non-Q scoping analysis. More detailed Q analyses done as future work may shrink or expand the preliminary list of DBEs resulting from the analysis documented in this section.

#### 10.1.3.2 Preliminary Hazards Analysis Results

Table 10.1-1 documents the results of a preliminary hazards analysis of all initiating events identified as applicable to the preclosure phase of the repository ACD. For the surface facilities, most identified events occur in the Waste Handling Building. A few events are postulated to occur outdoors, and a few occur in the Cask Maintenance Facility. No significant events occurring in the Waste Treatment Building (WTB) were identified.

#### 10.1.3.3 Selection of Design Basis Events

To optimize the use of safety analysis resources in the performance of detailed, quantitative DBE analysis, a screening process is applied to the events in Table 10.1-1 using the methodology discussed in Section 10.1.3.1. The DBE screening process discussed above is documented in Table 10.1-2. After application of this process, the following events remain as credible and bounding DBEs applicable to the repository ACD.

The following two lists are the result of preliminary work to date. Specifically, some of the following events may be found to be not credible or not limiting and may therefore be deleted. Other events also may be added to this list as a result of subsequent analyses:

Surface Facilities Design Basis Events List:

Internal Events:

1. SFC Drop - vertical, not onto DC
2. SFA Drop - vertical, not onto DC, but possibly onto another SFA
3. HLWC Drop - vertical, not onto DC, but possibly onto another HLWC
4. Shipping Cask Slapdown - impact limiters removed, lid removed
5. WP Slapdown
6. SFA Drop onto Sharp Object
7. WP Drop onto Sharp Object
8. SFC Drop onto an Unsealed DC
9. Automatic Center of Gravity Lift Fixture Drop onto WP
10. Non-mechanistic Failure of WP in the Waste Handling Building
11. Non-mechanistic WP Failure Outdoors (Note: Assumed to occur following Transporter Derailment or Collision and WP Ejection, none of which is expected to cause a credible mechanistic WP failure)
12. Decon System Failure - Internal Flooding, into/around WP (criticality threat)
13. Fuel Damage by Laser Radiation/Heat/Burnthrough During Welding Process

External Events:

14. Design Basis Earthquake
15. Design Basis Flood
16. Design Basis Lightning
17. Design Basis Ashfall
18. Design Basis Chemical/Toxic Gas Release
19. Design Basis Sandstorm
20. Design Basis Tornado
21. Design Basis Wind
22. Design Basis Industrial Accident
23. Design Basis Intrusion
24. Loss of Offsite Power/Station Blackout
25. Design Basis Geological Static Fracturing (surficial fissuring, impact fracturing, hydraulic fracturing)

Subsurface Facilities Design Basis Events List:

Internal Events:

1. Non-mechanistic WP Failure in Main Drift (Note: Assumed to occur following:
   a. Transporter Derailment or Collision and WP Ejection
   b. Emplacement Rail Car Derailment or Collision and WP Ejection
   c. WP Rail Car Rollout from the Transporter

   none of which is expected to cause a credible mechanistic WP failure)

2. Steel Set Drop onto WP
3. Loss of WP Cart Restraint in Sloped Emplacement Drift
4. Thermal Cycling of WP Due to Blast Cooling for Retrieval

External Events:

5. Design Basis Earthquake
6. Design Basis Flood
7. Design Basis Intrusion
8. Loss of Offsite Power/Station Blackout
9. Design Basis Geochemical Alterations
10. Design Basis Waste and Rock Interaction
11. Design Basis Geological Static Fracturing (surficial fissuring, impact fracturing, hydraulic fracturing)

#### 10.1.3.3 Preliminary Assessment of Repository Design Capability to withstand Design Basis Events

As discussed in Section 10.1.2, the existing applicable requirements documents already have requirements that address certain potential design basis events. As a result, the repository design presented in this report includes such "potentially required" prevention and mitigation functions as:

- Confinement Systems
- "Sealed" Buildings
- Filtered HVAC Supply and Exhaust
- Elevated Stack
- Preclosure Controlled Area Boundary
- Technical Specifications for Operations
- Operating Procedures
- Fire Barriers
- Fire Detection and Suppression Systems
- Control of Fuels (Types and Quantities)
- Control of Ignition Sources
- Flood Protection
- Lightning Protection System
- Building Design Loads
- Designed for Natural Phenomena, including Seismic.

It is concluded that the repository design presented in this report is adequate to prevent or mitigate potential DBEs within regulatory requirements. While not specifically identifying a complete list of DBEs, the existing requirement documents require the inclusion of many of the potential DBEs in Table 10.1-2 in the design bases of repository SSCs (e.g., natural phenomena, radiological protection). As a result many preventive or mitigative features have been included in the SSC design such that reasonable assurance is provided that the proposed design can withstand the potential Design Basis Events identified in Table 10.1-2 without significant modifications to the design. Since many of the repository SSCs are already on the *Q-List* (at a high level), the current radiological safety classification of the existing design should bound the formal identification of SSCs important to safety. SSCs will be reclassified as part of subsequent design, as required by DBE analysis results.

#### 10.1.3.4 Administrative Controls

Each time the DBE analyses take credit for the operability of IRS SSCs to prevent or mitigate an event, they will identify the need for operating license conditions, technical specifications, procedures, and other administrative controls to complement the design. These controls will be required to preserve the safety design basis during the preclosure operational phase of the repository and will be applied under the quality assurance (QA) program as part of the repository design basis. DBE analyses also will identify other administrative controls, such as access controls, that can be used to minimize the frequency or consequences of the analyzed events.

#### 10.1.3.5 Emergency Actions

DBE analyses also will contribute to the development of the Emergency Plan for the repository. Analysis of the timing and severity of DBEs will become part of advance plans for a required evacuation of the site or surrounding population and other protective measures taken to limit the effects of an event.

#### 10.1.3.6 Beyond Design Basis Events

Some DBEs, and even some non-DBEs (initiating events that have been screened out for consideration as DBEs because they are not credible) may have aspects that warrant additional consideration as " residual risk." Residual risk is the risk that the regulator is asked to accept in licensing the facility for operation. DBEs that are natural phenomena hazards, such as seismic activity, occur across a continuous spectrum of severity versus frequency. The portion of the frequency spectrum beyond the threshold of credibility (frequencies less than once per one million years) is " beyond the design basis," part of residual risk.

Although they are beyond the design basis, system responses to these low probability-high consequence events will be reviewed as future work to identify possible low impact design changes or operating philosophies that either decrease the frequency of occurrence even further, or decrease the consequences if the event were to occur. In accordance with the mandate of NUREG-1318, these analyses are performed to identify areas where it would be cost effective to reduce significantly the overall risk of low probability-high consequence events.

### 10.2.1 Introduction

#### 10.2.1.1 Purpose

The surface and subsurface facilities will be handling a significant quantity of highly radioactive materials. It is imperative that these facilities be designed in such a way to afford the maximum amount of protection from radiation and its effects to the operating personnel, the environment, and the general public. This section describes the radiological considerations that have been incorporated into the ACD of the MGDS. Requirements and criteria that will result in a sound radiological protection control program have been incorporated into the MGDS. These include items important to radiological safety (QA-1 Classification, QAP-2-3/Rev. 7) and items important to occupational radiological exposure (QA-7 Classification, QAP-2-3/Rev. 7). This section discusses the overall program which will assure that the MGDS will be a radiologically safe facility to operate.

#### 10.2.1.2 Summary of Studies

A. ALARA Design Program – A documented ALARA Program has been established to support the study and design activities in such a manner as to meet DOE and operator ALARA criteria, ensure that during normal operation of the MGDS, exposures are ALARA, and design into the MGDS engineering the controls to handle anticipated abnormal operations. The ALARA Program will serve as a basis for the operational ALARA program that will be established at the start of repository operations by the MGDS operator.

B. Preliminary Dose Assessment for the MGDS Surface Facility Waste Handling Operations – The preliminary dose assessment was made for each step in each operation that occurs at the surface facilities. This assessment was made for each of the known types of transportation casks and served to identify the points in the concept of operations where a particular amount of attention should be paid to an operational step in order to reduce exposure.

C. Internal Radiation Streaming for the Transporter Cask/Multi-Purpose Canister Radial Gap – This study examined the radiation level that would be anticipated to occur above an multi-purpose canister placed in a transportation cask with the cask lid removed. The radiation resulting from streaming and scatter through a gap between the canister and the inside cask wall was determined to be significant even though the top of the canister itself is semi-shielded.

### 10.2.2 Design Input

#### 10.2.2.1 Design Requirements

All text in this section is excerpted directly from the RDRD, which is the reference source for repository requirements. The specific RDRD requirements quoted below are considered applicable to aspects of radiological safety. Other RDRD requirements, which may apply in a more general way, are not included here such as those dealing with accident scenarios discussed in Section 10.1.

3.2.2.1 General Requirements

A. The Geologic Repository Operations Area shall, to the extent practicable, be designed and constructed to use procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA. ALARA principles shall be based on the applicable sections of NRC Regulatory Guides 8.8 and 8.10.

B. The Geologic Repository Operations Area design and operations shall include provisions for controlling doses such that, when approved operational procedures are followed, the exposure dose limits specified in 10 CFR 20.1201 for occupational doses, and 10 CFR 20.1301 for individual members of the public, are not exceeded.

C. The Geologic Repository Operations Area shall be designed so that, until permanent closure has been completed, radiation exposures and radiation levels and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in 10 CFR 20 and environmental standards for radioactivity as established by the EPA and specified in this document.

D. The Geologic Repository Operations Area shall provide means to limit the levels of radioactive materials in effluents, during normal operations, anticipated occurrences, and under accident conditions. Releases shall be limited as follows:

Releases shall be limited as follows:

1. Under normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to: planned discharges of radioactive materials, radon and its decay products excepted, to the general environment; direct radiation from Repository operations; and any other radiation from uranium fuel cycle operations within the region. [TBR]

2. Under accident conditions, the annual dose equivalent shall not exceed [TBD].

E. The disposal system shall be designed to meet the individual protection requirements specified by 40 CFR 191.15 [TBR].

3.2.2.2 Public Protection

A. Repository facilities shall be designed to operate so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem

(1 mSv) in a year, exclusive of the dose contribution from the facility's disposal of radioactive material into sanitary sewerage in accordance with 10 CFR 20.2003. However, the facility may apply for prior NRC authorization to operate up to an annual dose limit for an individual member of the public of 0.5 rem (5 mSv) in accordance with 10 CFR 20.1301(c).

B. If members of the public have access to controlled areas, the limits for members of the public shall continue to be applicable to those individuals.

C. Repository facilities shall be designed to operate so that the dose in any unrestricted area from external sources does not exceed 0.002 rem (0.02 mSv) in any one hour.

3.2.2.3 Airborne Radioactive Material Control

A. Concentrations of radioactive material in air shall to the extent practicable be controlled through the use of process or other engineering controls (e.g. containment or ventilation).

B. When it is not practicable to apply process or other engineering controls in restricted areas to control the concentrations of radioactive material in air to values below those that define an airborne radioactivity area, the repository shall, consistent with maintaining the total effective dose equivalent ALARA, have the capability to increase monitoring and limit intakes by one or more of the following: control of access, limitation of exposure times, use of respiratory protection equipment, or other controls.

C. The Geologic Repository Operations Area shall be capable of implementing and maintaining air sampling sufficient to identify potential hazards, to permit proper protective equipment selection, and to estimate exposures.

3.2.2.4 Radiation Monitoring

A. Waste handling facilities shall be equipped to monitor occupational exposures to radiation at levels sufficient to demonstrate compliance with the occupational dose limits of 10 CFR 20, including:

1. Adults likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of the limits in 10 CFR 20.1201(a).

2. Minors and declared pregnant women likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of any of the applicable limits in 10 CFR 20.1207 or 10 CFR 20.1208.

3. Individuals entering a high or very high radiation area.

B. Equipment to monitor, as specified in 10 CFR 20.1204, the occupational intake of radioactive material by and assess the committed effective dose equivalent to:

1. Adults likely to receive, in 1 year, an intake in excess of 10 percent of the applicable annual limit on intake in Table 1, Columns 1 and 2, of appendix B to 10 CFR 20.1001 - 10 CFR 20.2401.
2. Minors and declared pregnant women likely to receive, in 1 year, a committed effective dose equivalent in excess of 0.05 rem (0.5 mSv).

C. Visual and audible alarm systems shall be provided to alert workers if radiation levels exceed established design levels. Visibility and audibility of alarms shall be in accordance with NRC Regulatory Guide 8.5.

D. Radiation monitors for monitoring radiation levels at various locations surrounding the site shall be provided. Appropriate monitors for ambient radiation, water, and airborne gaseous and particulate radioactivity will be used. Wells for monitoring radioactive contamination of groundwater shall be provided as required.

3.2.2.7 Transportation Protection

The Repository Segment shall be provided with the capability to comply with the requirements for packaging and transporting radioactive materials contained in 10 CFR 71 and 49 CFR 173 when shipping licensed radioactive material from the MGDS.

3.2.4.3.2 High Radiation Area Access Control

A. Access to high and very high radiation areas shall be controlled in accordance with the requirements specified by 10 CFR 20.1601 and 20.1602.

B. The repository design shall provide at each entrance or access point to a high radiation area:

1. One or more of the following features:

a) A control device that, upon entry into the area, causes the level of radiation to be reduced below that level at which an individual might receive a deep-dose equivalent of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

b) A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry.

c) Entryways that are locked, except during periods when access to the areas is required, with positive control over each individual entry.

2. Or, in place of the controls required by 3.2.4.3.2.B.1 above, continuous direct or electronic surveillance that is capable of preventing unauthorized entry.

3. Or an alternative method for controlling access to high radiation areas approved in advance by the NRC.

4. The controls required by subparagraphs 1 and 3 above shall not prevent individuals from leaving a high radiation area.

5. Control shall not be required for each entrance or access point to a room or other area that is a high radiation area solely because of the presence of radioactive materials prepared for transport and packaged and labeled in accordance with the regulations of the Department of Transportation provided that the packages do not remain in the area longer than 3 days and the dose rate at 1 m from the external surface of any package does not exceed 0.01 rem (0.1 mSv) per hour.

3.2.4.4 Radioactive Materials Monitoring

The Repository Segment shall be equipped to monitor the external surfaces of packages and casks known to contain radioactive material for radioactive contamination and radiation levels in compliance with 10 CFR 20.1906.

3.2.4.5.1 Shielding Design

A. Normally Occupied Areas. The shielding design basis shall limit the maximum exposure to an individual worker to one-fifth of the annual occupational external exposure limits. Within this design basis, personnel exposures must be maintained ALARA. Specifically, the shielding should be designed with the goal of limiting the total effective dose equivalent to less than one rem per year to workers, based on their predicted exposure time in the normally occupied area. The effective dose equivalent is the sum of all contributing external penetrating radiation (gamma and neutron). In addition, appropriate shielding must be installed, if necessary, to minimize non-penetrating external radiation exposures to the skin and lens of the eye of the worker. In most cases, the confinement barrier or process equipment provides this shielding.

B. Intermittently Occupied Areas. Shielding and other radiation protection measures shall be provided for areas requiring intermittent access, such as for preventive maintenance, component changes, adjustment of systems and equipment, and so forth, with the goal of limiting dose rates based on occupancy, time, and frequency of exposure to one rem per year.

C. Concrete. Concrete radiation shielding design shall comply with ANSI/ANS 6.4 and ACI 349 and shall consider the material specifications of ANSI/ANS 6.4.2 where it provides a critical confinement or structural function. For other shields, ACI 318 is appropriate and provides adequate strength for design earthquake loads.

D. Penetrations. Design of shield walls shall avoid straight-line penetrations to prevent radiation streaming.

3.2.4.5.2 Remote Shielded Operation

Remote shielded operation (i.e., with remote handling equipment such as remote manipulators) shall be considered where it is anticipated that exposure to hands and forearms would otherwise approach the dose requirements in Section 3.2.2 or where contaminated puncture wounds could occur.

### 10.2.2.2 Design Assumptions

Assumptions relevant to evaluation of radiological concerns, as stated in the Controlled Design Assumption Document, are noted as follows:

A. The Surface Facilities that house radioactive materials or in which work is performed on radioactive materials will be designed to control occupational exposures to ALARA and less than 500 mrem per year.

B. ALARA studies will be conducted as needed to establish the allowable dose rates upon which various radiological safety calculations will be based.

Additional assumptions regarding radiological concerns are required in order to proceed with current design related issues. The more significant of such issues include the following:

C. Limiting Repository Waste Characteristics: The most limiting waste that will be analyzed for shielding purposes will be the highest burnup light water reactor fuel that appears in the Characteristics Data Base. Based upon the current database, this limiting value is 60,000 MWd/IHM. Additionally, the limiting waste will be based upon the uncanistered fuel disposal container that contains fuel that has been allowed to decay for a minimum of 10 years prior to receipt at the repository.

D. ALARA Evaluations: The facility ALARA program as describes in detail how to calculate the various factors that are to be considered in an ALARA evaluation. Not included is a recommended value for "reasonableness." That is, how much should be expended to save a future man-rem of exposure. NRC guidance on this issue has been published in 10 CFR 50, Appendix I for Nuclear Power Reactor Effluents. No specific guidance is currently available in the Code of Federal Regulations for a HLW Repository design.

E. Dosimetry Calculations: Evaluations of radiation fields associated with HLW require translation into equivalent dose rate values of rem/hr. In general, such radiation fields are energy dependent with values from MeV values down to values approaching zero energy. The calculation of dose rate for both gamma fields and neutron fields is dependent upon the energy of the particular photon or neutron particle being evaluated which is a reflection of the relative effectiveness in producing damage to target material. Energy dependent conversion factors have been recommended by ANSI/ANS (1991) for both gamma and neutron field evaluations. However, a recent International Commission on Radiological Protection study recommends doubling the values for neutron field conversions into dose rate based upon a re-evaluation of world-wide dosimetry data for the effects upon human tissue. Most U.S. authoritative organizations have concurred with this recommendation, including the DOE in the most recent issue of the DOE Radiological Control Manual. However, the latter document was not specific in indicating which table values for neutron fields were to be doubled. Consequently, it is recommended that the ANSI/ANS (1991) tabulated values for neutron field conversion into dose rate be doubled in accordance with the recommendation of the International Commission on Radiological Protection consistent with ALARA. The existing guidance values for gamma field conversion into dose rate will be used as currently stated in ANSI/ANS (1991).

### 10.2.3 Design Considerations

#### 10.2.3.1 General Considerations

This section describes the anticipated radiological safety concerns and considerations associated with the design and operation of the MGDS. The DOE policy on radiological control and safety for the design and operation of the MGDS is summarized below.

A. ALARA – Personal radiation exposure shall be maintained ALARA. Radiation exposure of the work force and public shall be controlled such that radiation exposures are maintained below regulatory limits and there is no radiation exposure without commensurate benefit.

B. Ownership – Each person involved in radiological work is expected to demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation and radioactivity.

C. Excellence – Excellent performance is evident when radiation exposures are maintained well below regulatory limits, contamination is minimal, radioactivity is well controlled and radiological spills or uncontrolled releases are prevented.

Low-level radioactive waste materials are received from operational areas within the RCA. These secondary waste materials are primarily generated from decontaminating the surface of casks, canisters, from contamination coming off bare fuel assemblies, and from other equipment that has come into contact with contaminated materials. These low-level wastes are typical for nuclear fuel cycle facilities with hot cell operations. The radioactive sources in the waste materials will produce alpha, beta and gamma type radiations, with the gamma radiations providing the most significant whole body exposures and the alpha and beta radiations providing the most significant ingested exposure. There will also be some neutron radiations; however, these radiations constitute a small percentage of the total radioactive emissions.

**Direct Exposures**

Direct exposures will primarily be caused by the gamma radiations although there are a smaller amount of neutron radiations present. Direct exposures are minimized by limiting the quantity of the source materials, biological shielding, distancing personnel from the radiation sources, and reducing personnel exposure time. Section 10.2.3.3 identifies the radiation protective measures that have been designed into the various MGDS facilities to reduce and/or eliminate personnel direct exposures according to ALARA.

The ACD design includes general protective measures to minimize direct exposure consisting of permanent and temporary shielding, Radiation Area Monitors, Constant Air Monitors, remote operations and administrative procedures.

**Internal Exposures**

Internal exposures occur as a result of radioactively contaminated material entering the body by eating, breathing, or absorption through cuts, bruises, etc. Ingested exposure has the potential to be the most damaging type of exposure because of its proximity to sensitive body organs and because it takes time to egest the material from the body. Ingested exposures are minimized by minimizing direct contact between airborne contamination and personnel and by the use of good radiological safety practices.

The MGDS designs include protective measures consisting of Constant Air Monitors to measure the contaminated particulate matter in the air, the availability and use of breathing devises such as respirators, the use of glove boxes for contact operations involving materials that are known to be contaminated, and zoned heating, ventilation, and air conditioning (HVAC) confinement systems to control the spread of contamination and minimize the potential for contact with the operating personnel.

The wastes are packaged and immobilized to physically control and prevent contamination release during interim staging and shipping.

### 10.2.3.2 MGDS Site Radiological Control Program

It is the policy of the DOE and its contractors to conduct radiological operations during the design, operation, caretaker, and closure periods in a manner that protects and promotes the radiological safety of employees, visitors and members of the general public. This policy will be enforced through the implementation of an effective radiation control program, as approved under NRC license, that identifies and controls radiological hazards. The radiation control program will ensure that the receipt, possession, use, transfer and disposal of licensed materials are conducted such that the total dose to an individual does not exceed the standards for radiation protection prescribed in 10 CFR 20.

As part of the implementation of this program, in accordance with the classification QA-7 in QAP-2-3/Rev. 7, the operator will use radiation protection and awareness training, administrative procedures, personnel monitoring and engineering controls and techniques, that are based on sound and accepted radiation protection principles, to maintain occupational doses and doses to members of the general public that are ALARA. The program will be assessed and audited periodically to determine program content, implementation and effectiveness. The program will be modified, as warranted, to ensure compliance with the standards for radiation protection.

The key to conducting and maintaining an effective radiation control program is the individual employee. Each employee is expected to plan and conduct their radiological activities that promotes the achievement and maintenance of radiation doses ALARA. In support of the employee(s), supervisors and managers are accountable for ensuring that all personnel entering radiological areas and/or conducting radiological activities are properly trained and monitored, and that radiological activities are planned, authorized, and performed according to procedure and in a radiologically safe manner.

The Radiological Control Manager for the MGDS has the operational responsibility for the implementation program elements and maintenance of the radiation control program to meet regulatory requirements. Prior to the initiation of any radiological operation and during the conduct of such operations, the Radiological Control Manager is responsible for the review and approval of the activities associated with the operation to ensure that personnel doses are less than regulatory standards and that doses are maintained ALARA. Any activity which involves the use of radioactive materials, ionizing radiation producing equipment and/or involves the monitoring of personnel to ensure compliance with regulatory standards for radiation protection will be reviewed by the MGDS ALARA Committee.

The MGDS ALARA Committee will consist of management representatives from those divisions/organizations that conduct radiological operations and/or monitor personnel radiation doses. The Committee has the responsibility for the review and evaluation of radiation doses to ensure that sound radiological principles are employed in the conduct of those operations. The Committee will recommend, on the basis of the radiological protection evaluation, that the activity either be approved or denied. In addition to the review and evaluation of specific radiological operations, the ALARA Committee is responsible for determining the effectiveness of the radiological control program

All radiation areas within the MGDS facility area will be posted, in accordance with regulatory requirements, in order to control access to those areas and to maintain personnel radiation dose ALARA. In addition to posting areas, all containers/packages containing licensed radioactive materials will be labeled in accordance with regulatory requirements.

Radiological monitoring of employees and conducting radiation surveys will be performed to demonstrate compliance with regulations, meet license requirements and to meet the goals of the radiation control program. Monitoring of internal and external occupational doses will be conducted as required by regulations. The purpose of these activities will be to define and evaluate the extent of radiation levels, concentrations or quantities of radioactive materials, and potential radiological hazards that may be present. The results of these activities will be maintained as required by regulation. Area surveys and individual personnel monitoring results will be available to the individual employee upon request.

### 10.2.3.3 Design Specific Considerations

A. Site Access and Control – Transportation casks entering the site (RCA) will undergo monitoring for identification, security, and radiological inspection. The cask carrier will then be attached to the on-site prime mover and moved either into a temporary parking location or directly to the Staging area. If the casks arrive by truck, the truck will transport the cask to the required location. The shipping hardware, which consists primarily of the impact limiters and the personnel barrier, will be removed The carrier and the transportation cask will then be moved into the Waste Handling Building by the on-site prime mover.

B. Waste Handling Building – The Waste Handling Building is the primary location of the surface facilities. It is in this building that the majority of waste handling operations take place and is the only facility in which either bare waste or canisters are exposed. The operations of the facility, the facility layout, and the equipment that it takes to perform the operations are described elsewhere in this report; however, certain features have been incorporated into the Waste Handling Building design for the specific purpose of providing the necessary radiological protection for both operational and public radiological protection. These features are listed below:

- Air lock building entries and exits
- Cask transfer ports are shielded and are designed to eliminate or minimize the spread of contamination. They will be remotely operated to eliminate or minimize personnel radiation exposure.
- The cells in which the operations take place are shielded and all operations will be remotely performed.. Associated equipment such as shielding windows for direct viewing, television cameras for indirect and/or close up viewing, microphones for sound, mechanical and electromechanical manipulators for remote handling, and other remote handling tools will be provided.
- The building ventilation system is designed to insure the containment according to the applicable requirements.
- Provisions have been incorporated into the design to accommodate the normal maintenance activities such as manipulator repairs, decontamination, filter changeouts, etc.

C. Cask Maintenance Facility – The Cask Maintenance Facility at the MGDS services the transportation casks in which multi-purpose canisters and uncanistered SNF are delivered to the repository from their various points of origin. In addition, the Cask Maintenance Facility services the cask transporters and any ancillary equipment (personnel barriers, impact limiters, campaign kits, etc.) associated with the cask shipment. Cask, transporters, and equipment are inspected, tested, repaired, decontaminated, and otherwise maintained as required to keep the cask fleet in operation. Operations of the facility, the facility layout, and the equipment it takes to perform the operations of the facility are described elsewhere in this report. However, certain features have been incorporated into the Cask Maintenance Facility design for the specific purpose of providing the necessary radiological protection for both operational and public radiological protection. These features are listed below:

- Air locks between each confinement zone within the building
- Shielded radwaste staging areas
- A pool to minimize exposure and contamination
- Direct piping to a filtered HVAC system for cask purging
- An underwater vacuum system for cask interior cleaning
- Underwater closed-circuit television system for indirect and close up viewing
- A building ventilation system designed to enhance contamination control and provide containment according to the applicable regulations
- A building layout that allows for similar confinement zones to be placed together
- Provisions have been incorporated into the design to accommodate the normal maintenance activities.

D. Waste Treatment Building – Site generated secondary waste will be produced in the course of repository operations and maintenance. These wastes will include low-level radioactive waste, hazardous waste, and a small amount of mixed waste. The Waste Treatment Building is the location where these waste materials will be prepared for final disposition. The materials that will be processed in this facility will contain only low amounts of radioactivity and will have the potential for only small amounts of direct exposures. The main radiological protection in the Waste Treatment Building will be for ingested exposures and will consist of a controlled building HVAC systems, extensive constant air Monitoring systems, glove boxes, hoods, and personnel monitoring systems.

E. Waste Package Transporter – The waste package transporter will convey the final Waste Package into the repository for final emplacement and will be pulled by a single primary locomotive as described in Section 8.6. If required, the waste package transporter will also be used in the event that waste package retrieval is required. The waste package transporter will be designed to provide sufficient shielding around the waste package in order to minimize personnel hazards during inspection, maintenance, and transport activities. The final design, and maximum radiation exposure rate, will be determined using an ALARA type of analysis. This is expected to include a tradeoff study between the waste package transporter weight/size restrictions. The external radiation exposure rate is expected to be less than 100 (mrem) at 1 m from the outside surface, which, combined with suitable administrative restrictions, should provide adequate personnel protection.

F. Waste Package Emplacement – Emplacement of the waste package will be, for the most part, performed remotely with the possible use of a manned position inside of the primary locomotives. Local shielding of the operator station will be required for such a manned position in order make such a location permissible. Local shielding may also be required to support the control, alarm, and surveillance equipment that is needed for each emplacement drift as well as all other subsurface facilities.

G. Waste Package Backfill – Backfill, although not required, may nonetheless be considered in the future, Section 8.8. Should this be needed, shielding of critical controls, sensors, and monitors necessary during backfill will be required. Additionally, some shielding may be required of specialized primary equipment to ensure reliability in the harsh emplacement drift environment.

H. Waste Package Retrieval – Retrieval may be a relatively simple process or it might involve a waste package that has been buried by a rockfall. Specific radiation design solutions may be required to protect against the potential effects of both direct radiation and against the spread of loose radioactive material in the case of a breached waste package.

I. Underground Ventilation – Separate ventilation systems are provided for the development and emplacement areas of the repository as described in Section 8.8. These are maintained at positive and negative pressures respectively in order to minimize the spread of contamination in the event of a leaking waste package for all potential conditions. Additionally, these systems are separated within the repository by physical air flow barriers.

### 10.2.4 Summary

This section described the initial activities that have occurred during the FY 1995 in the incorporation of radiological safety into the design of the surface and sub-surface facilities. Since radiological safety had not previously been a part of MGDS design activities, the programs and approaches were created to accommodate the most limiting of requirements that are given in DOE Order 6430.1A, 10 CFR 20, and other documents that have been discussed the previous sections. A Design ALARA Program was established with the help and cooperation of the Health and Safety group to incorporate an organized approach into the design activities that would support the various design activities, insure that radiological safety issues were identified and addressed, document findings for future reference, and provide a means of creating an operation that could be conducted