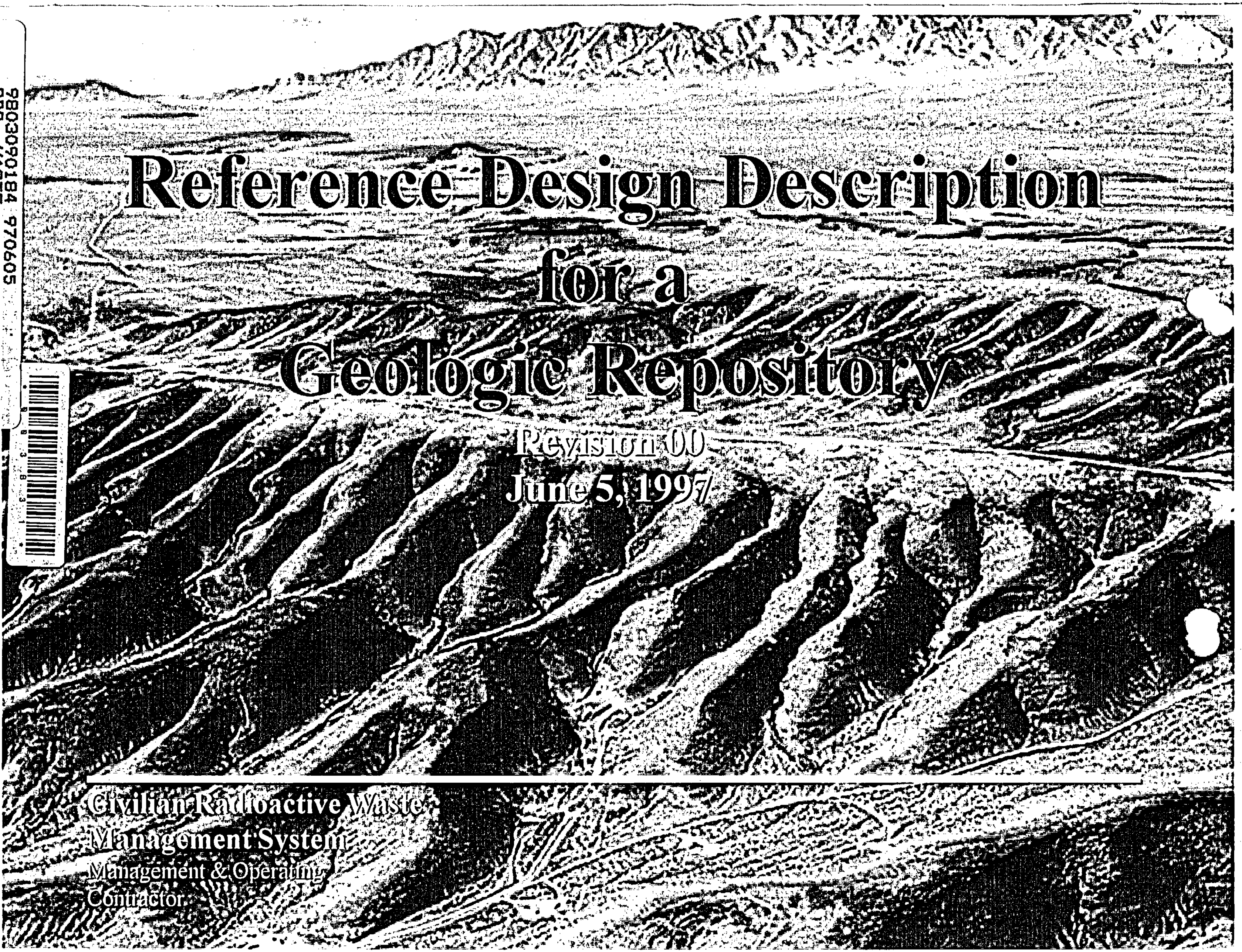

Reference Design Description for a Geologic Repository

Revision 00

June 5, 1997

Civilian Radioactive Waste Management System

Management & Operating Contractor

SUMMARY OF CHANGES

Revision 00 Initial issue

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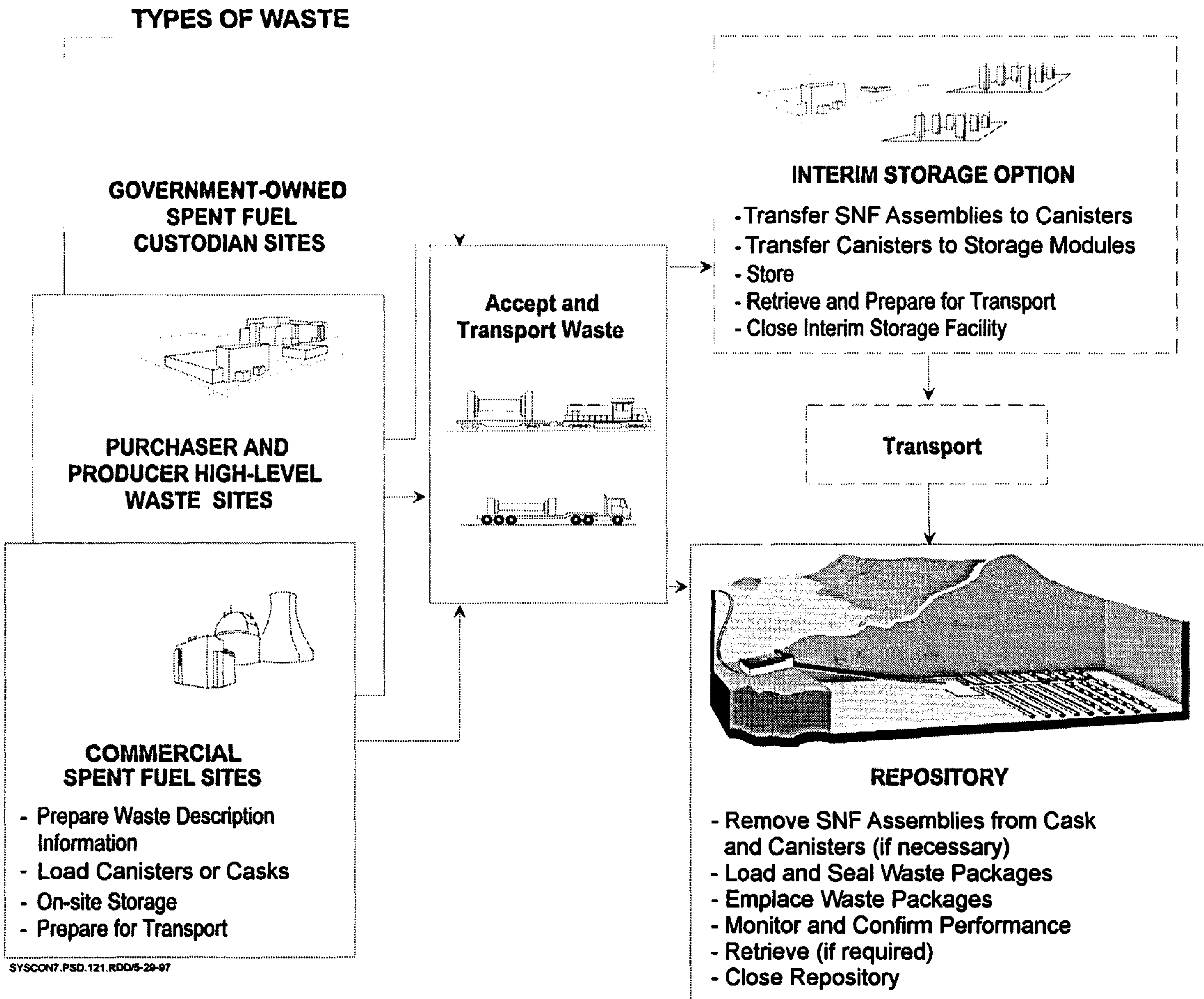
Civilian Radioactive Waste Management System Concept



INTRODUCTION

This document describes the current design expectations for a potential geologic repository that could be located at Yucca Mountain in Nevada. It primarily addresses the reference design solutions; it also presents key design options. This Reference Design Description (RDD) looks at the surface and subsurface repository and disposal container design. Additionally, it reviews the expected long-term performance of the repository.

The reference design presented allows the disposal of highly radioactive material received from government-owned spent fuel custodian sites; purchaser and producer high-level waste sites; and commercial spent fuel sites. All design elements meet federal, state, and local regulations governing the disposal of high-level radioactive waste and protection of the public and the environment.

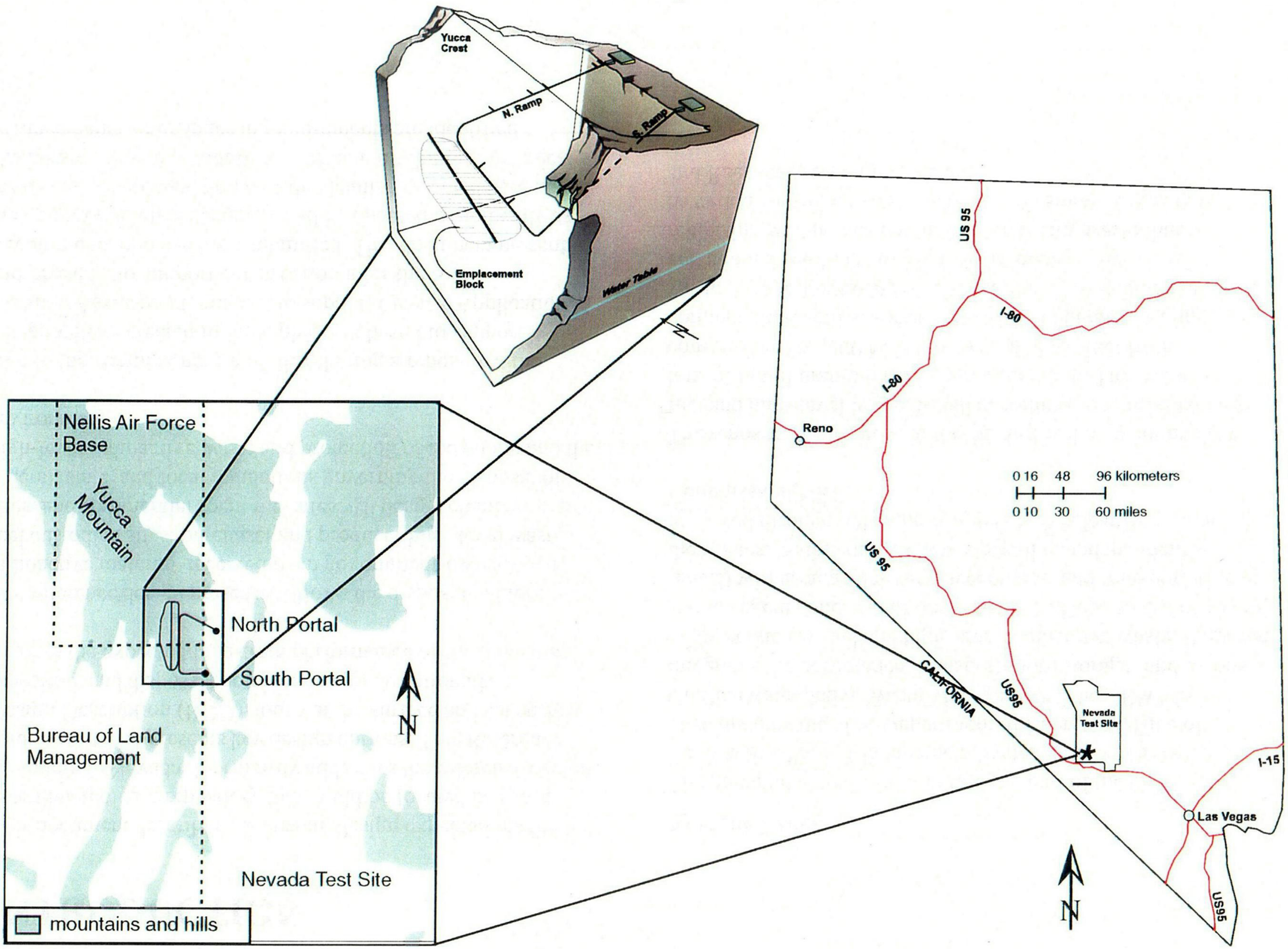
Due to the complex nature of developing a repository, the design will be created in three phases: phase I to support Viability Assessment, phase II to support License Application, and phase III to support construction after the Site Recommendation has been submitted. This document presents the current reference design. It will be updated periodically as the design progresses. Some of the details presented here may change significantly as more cost-effective solutions, technical advancements, or changes to requirements are identified.

System Roles

The potential repository is an integral part of the Civilian Radioactive Waste Management System (CRWMS) being developed by the U.S. Department of Energy's Office of Civilian Radioactive Waste Management. The CRWMS integrates the acceptance, transportation, storage, and disposal of spent nuclear fuel and high-level radioactive waste. Regional service agents under contract to the U.S. Department of Energy (DOE) will arrange delivery, acceptance, and transportation of the wastes. Safety of the CRWMS will be independently reviewed through licensing by the U.S. Nuclear Regulatory Commission (NRC).

The repository will provide for the disposal of spent nuclear fuel and high-level waste. It will accommodate 70,000 metric tons of initial uranium (MTU) or equivalent. That waste is comprised of 63,000 MTU of spent nuclear fuel from commercial reactors, about 4700 MTU equivalent of high-level waste from reprocessing of defense and commercial materials, and about 2300 MTU of DOE spent nuclear fuel. The repository will not accept or dispose of any waste that is hazardous or mixed waste subject to Resource Conservation and Recovery Act requirements.

Site Layout



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REPOSITORY SITE LAYOUT AND CAPABILITIES

Yucca Mountain is a potential site for a geologic repository. Yucca Mountain is located in an area of uninhabited desert on federal land in Nye County in southern Nevada, about 160 kilometers (100 miles) northwest of Las Vegas. The potential site is located beneath Yucca Crest, one of four major ridges of the mountain.

Surface Layout

The surface site layout will consist of the following four major surface areas:

- North Portal area: This 80-acre area will contain the radiological control area and the balance of plant facilities. This area will be used to receive and package the waste for emplacement.
- South Portal area: This 12-acre area at the southern entrance to the potential repository will support the excavation of the underground. Facilities will be provided for maintenance, warehousing, material staging, security, and transportation.
- Emplacement shaft area: This 3-4-acre site is located on the surface at the opening of the exhaust shaft. Facilities in this area will provide the emplacement ventilation exhaust fans and support their maintenance.
- Development Shaft Area: This half-acre site is located on the surface at the opening to the intake shaft and will have a facility to house the development intake fans and emergency hoisting system.

Subsurface Layout

The underground site layout will include the north and south ramps which will allow access to the emplacement block. The emplacement block will be located in the Topopah Spring area of Yucca Mountain, which is made up of welded tuff. This strong volcanic rock responds well to mechanical excavation and yields stable openings with appropriate ground support. The emplacement block will be located in the unsaturated region of the site.

The potential site for the emplacement block was chosen because it will be located in an area free of significant faults. This was determined after looking at detailed investigations of faults at Yucca Mountain.

Capabilities

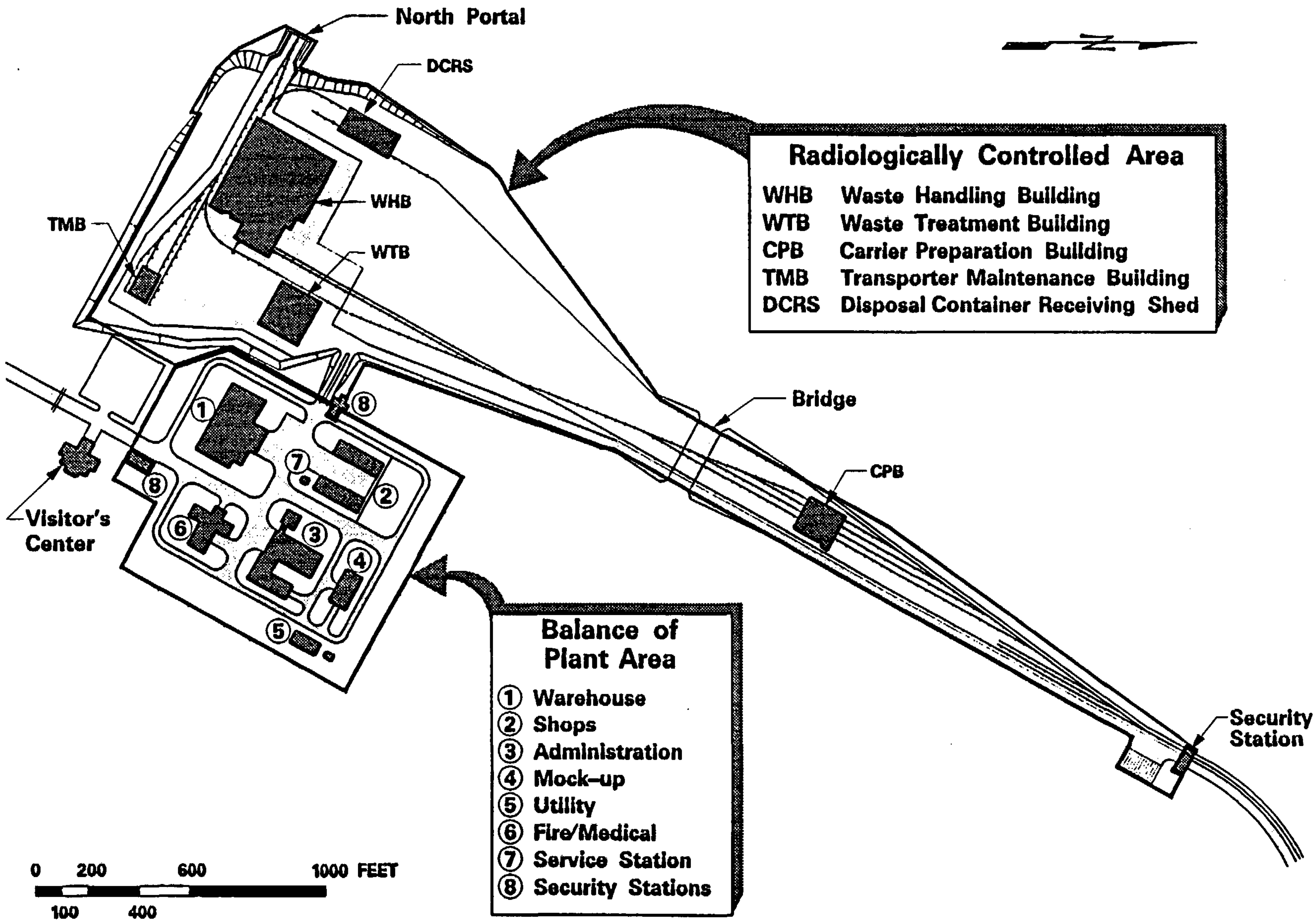
If Yucca Mountain is selected to become a geologic repository, the repository must then be licensed by the NRC for disposal of commercial spent nuclear fuel, high-level waste and DOE spent nuclear fuel at the site. The repository will receive, package, and dispose of the following types of waste:

- commercial spent nuclear fuel;
- commercial spent nuclear fuel in disposable canisters;
- commercial spent nuclear fuel in non-disposable canisters;
- DOE spent nuclear fuel in disposable canisters;
- DOE spent nuclear fuel in non-disposable canisters; and
- high-level waste in disposable canisters.

The repository will handle up to 3000 MTU/year of commercial spent nuclear fuel and up to 400 MTU/year of high-level waste and DOE spent nuclear fuel.

The waste will be emplaced in underground emplacement drifts. The distance between the drifts and the spacing of the waste packages within the drifts will be calculated to provide an areal mass loading of about 85 MTU per acre, which represents the density at which commercial spent nuclear fuel waste packages will be placed in the potential repository. High-level waste packages will be placed in drift areas between the commercial spent nuclear fuel packages.

North Portal Area



Surface Layout

The potential repository's surface layout will follow the necessary engineering standards to support the arrangement of the surface repository facilities and systems for safe and efficient operations. The repository's surface layout will have the following key features:

- organized around subsurface accesses;
- consideration of radiological exposure boundaries;
- consideration of flood areas, fault zones, and meteorological patterns;
- support for surface and subsurface operations (facility and transportation);
- consideration of preclosure radiological safety; and
- minimization of environmental impacts.

North Portal Area

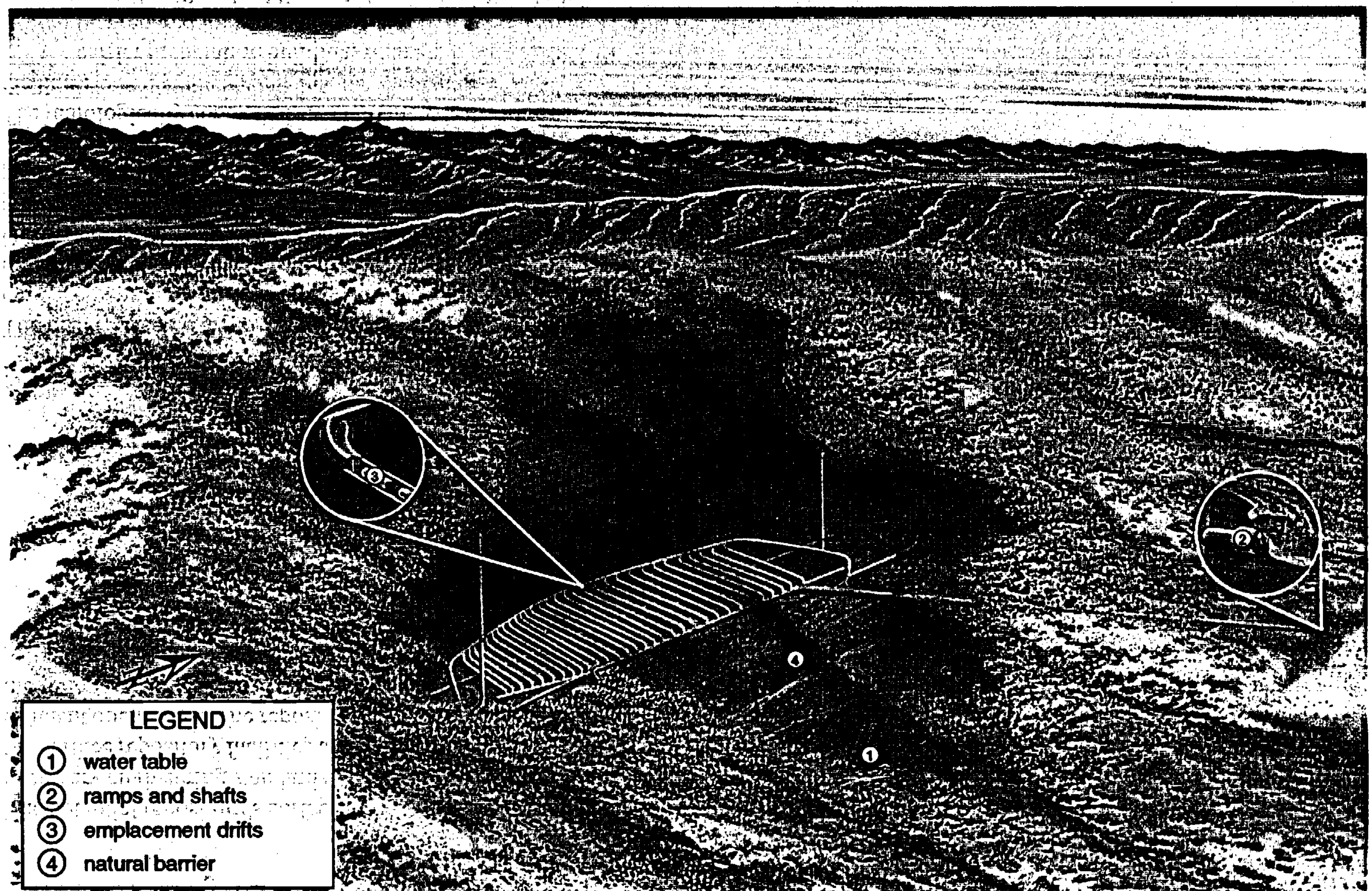
The materials to be disposed will be received and packaged for emplacement in an 80-acre area located at the northern entrance to the potential repository (the North Portal). The operations involving radioactive materials will be conducted in the radiologically controlled area and the support operations will be performed in the balance of plant area.

The radiologically controlled area will include the following facilities:

- carrier preparation building, where shipping casks will be prepared for removal from rail or truck carriers;
- waste handling building, where spent nuclear fuel assemblies and disposable waste canisters will be packaged into disposal containers;
- disposal container receiving shed, where empty disposal containers will be received and prepared for loading;
- waste treatment building, where low-level waste for off-site disposal will be treated; and
- transporter maintenance building, where the vehicles used to transport and emplace waste will be serviced.

The balance of plant area includes the following facilities: security stations, administrative building, fire/medical center, warehouse, central shops, motor pool and facility service station, mock-up building, utility building and visitor center.

Subsurface Facility



Subsurface Facility

The subsurface facility will include a main tunnel, accesses, alcoves, drifts, and boreholes. The subsurface facility will provide access to the underground for the emplacement of waste and overall repository stability through widely spaced emplacement drifts.

The subsurface facility's physical location and general arrangement, as well as the mountain's natural geologic barrier will provide long-term waste isolation. The subsurface facility will enhance the isolation characteristics of the waste packages by locating the emplacement drifts away from major faults and above the water table.

Design Description

Two inclined access ramps, two vertical ventilation shafts, and a waste emplacement block with main drifts and waste emplacement drifts make up the subsurface facility. Water will drain from the emplacement drifts toward the main drifts. The ramps and shafts will be sealed during the potential repository's closure phase.

The waste emplacement block will be located at least 200 meters (660 feet) below the surface and at least 100 meters (330 feet) above the water table. The block will cover 300 hectares (740 acres) and will accommodate about 11,000 waste packages in a large waste package and high thermal load configuration. The emplacement drifts in the block will run in an approximate east-west direction. The completed layout will involve about 150 kilometers (93 miles) of drifts.

The facility will contain two types of main drifts.

- Service main drift (including ramps) for access, which will have the following features:
  - 7.6 meters (25 feet) in diameter;
  - excavated using a tunnel boring machine; and
  - maximum grade in ramps of 2.7% to accommodate rail transport.
- Exhaust main drifts for ventilation, which will have the following features:
  - 7.6 meters (25 feet) in diameter;
  - excavated using a tunnel boring machine;
  - located 10 meters (33 feet) below the emplacement drifts; and
  - connected to emplacement drifts by a series of ventilation raises.

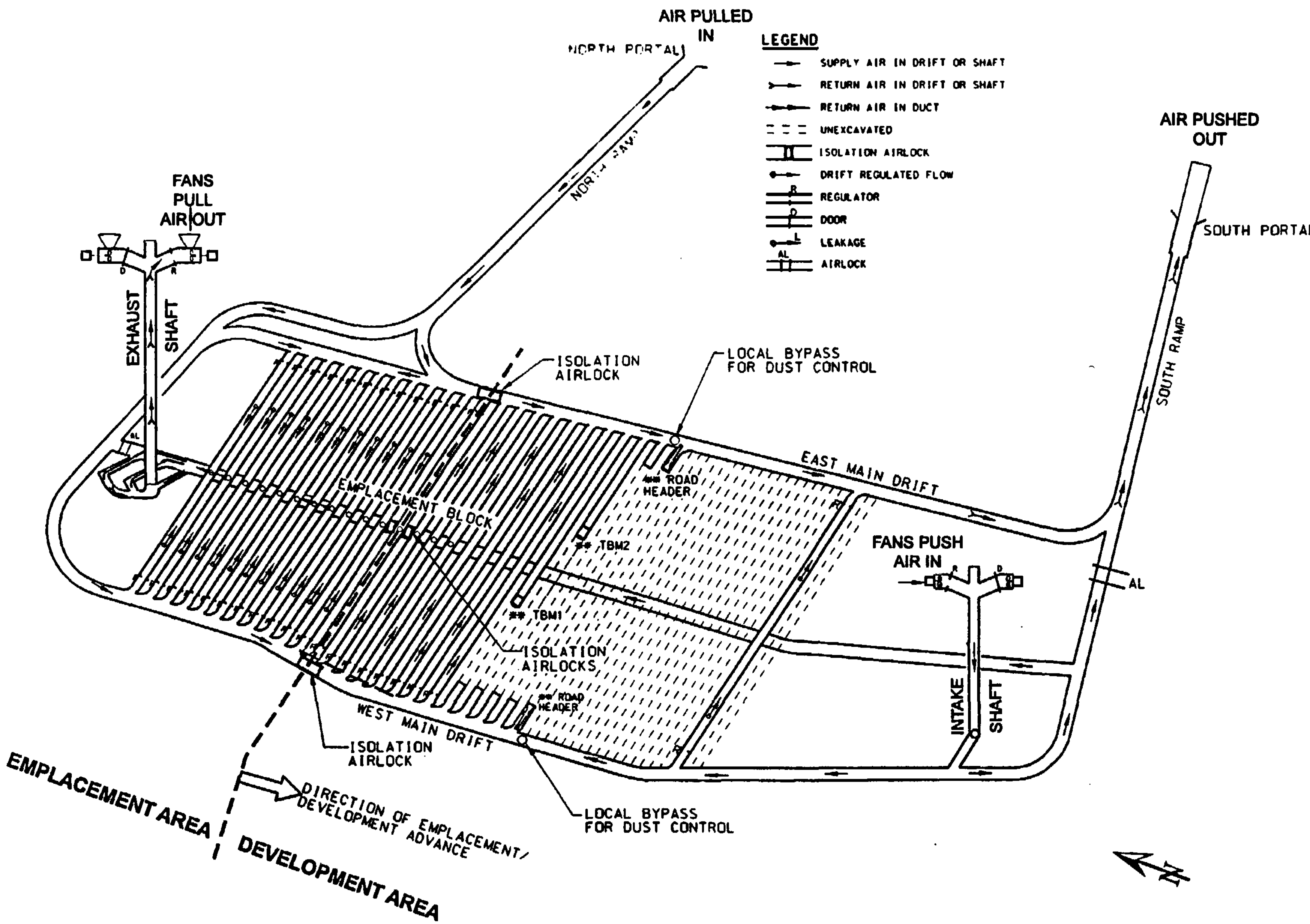
The emplacement drifts will be designed according to the following criteria:

- 5.5 meters (18 feet) in diameter;
- 28 meters (92 feet) spacing between centers of emplacement drifts;
- 500 meters (1640 feet) to about 1200 meters (3940 feet) in length with a riser from the exhaust main drift near the center of the emplacement drift;
- remotely controlled doors at the entrance to control access; and
- raised floor above the main drift to allow a waste package to be off-loaded directly out of the transporter in preparation for emplacement.

Approximately 5 percent of the emplacement drifts will be completed prior to the start of waste emplacement operations, The remaining 95 percent will be completed while waste is being emplaced in the completed drifts.

The rate of emplacement drift development will be determined based on the number of emplacement drifts, the emplacement strategy, the spacing of the waste packages, the spacing of the emplacement drifts and the number of tunnel boring machines used to excavate the drifts.

Subsurface Ventilation System



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Subsurface Ventilation System

The Subsurface Ventilation System will support the development and emplacement operations of the subsurface repository by providing

- air to personnel;
- confinement of radioactive particles; and
- limited temperature control of the underground facility based on air-flow volume and outside air temperature.

To prevent the spread of any unlikely radioactive releases from the emplacement area, the development and emplacement operations will be physically separated from each other, and each will have its own ventilation system and ramp access. A high efficiency filtration system will be used to capture any radioactive releases.

The system will consist of ducting, fans, seals, and electronic controls. It will interface with the surface for air intake and exhaust, electric power, and monitoring. Major equipment will be located above ground.

Design Description

During the operation phase, underground openings will be developed in parallel without interfering with waste emplacement or retrieval. Physical and functional separation of the two activities will be maintained using isolation air locks.

Two separate, independent ventilation systems will operate simultaneously during repository operations. One system will provide ventilation for the excavation operations required to develop the emplacement drifts, while the other will supply air to the waste emplacement operations. Temporary walls (isolation air locks) in the main drifts at the points that divide the two sides will keep ventilation of the two systems separate. As excavation and emplacement progresses, these walls will be moved to new points in the main drifts. This will provide access to newly excavated drifts for waste emplacement. Each area will have its own dedicated fans with appropriate backup capability.

The ventilation system on the subsurface development (excavation) side will

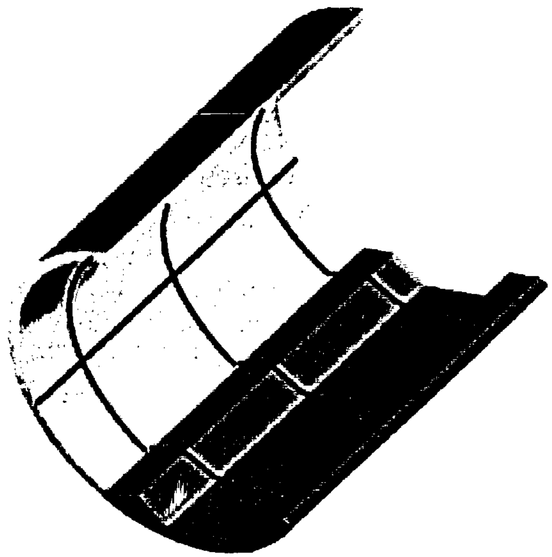
- force air into the subsurface excavation drifts by way of fans at the intake shaft;
- exhaust air through the south ramp; and
- maintain air pressure on the excavation side above the air pressure on the emplacement side.

The ventilation system on the emplacement side will

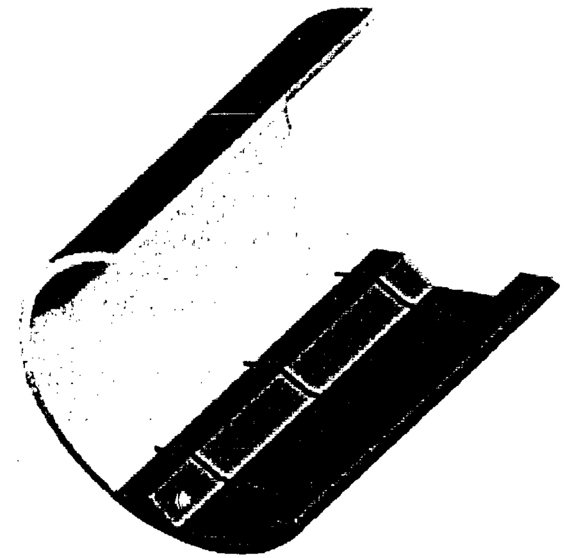
- pull air into the north ramp and emplacement areas using fans in the exhaust shaft;
- exhaust the air through the exhaust shaft;
- maintain a lower air pressure than on the excavation side of the subsurface layout; and
- contain high efficiency filters that will activate in the event subsurface contamination is detected.

This combination of systems will ensure that even in the event that one system shuts down, the pressure differential between development and emplacement will be maintained. This will ensure any potential radioactive releases are contained to the emplacement side.

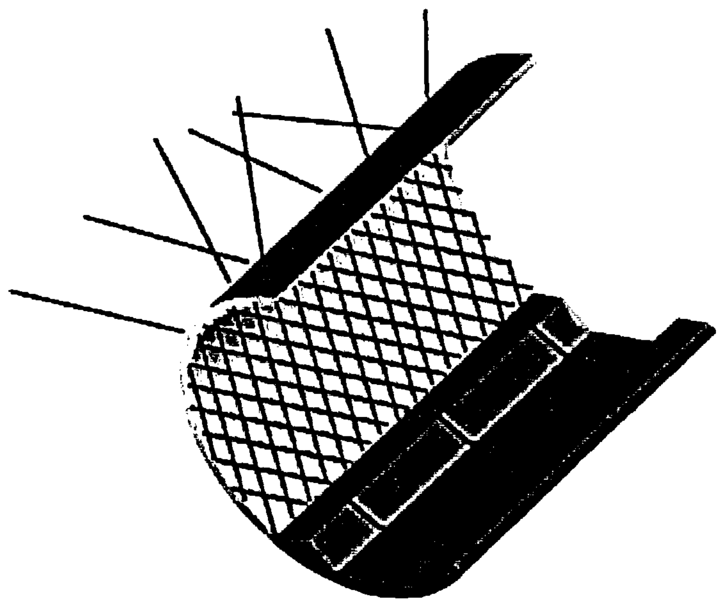
Ground Support System



PRECAST CONCRETE LINING



CAST-IN-PLACE CONCRETE LINING



ROCK BOLT & MESH SUPPORT

Ground Control System

The Ground Control System will provide for the safe construction and operation of the subsurface facility (main and waste emplacement drifts) by providing a concrete or steel lining for structural support in the main and emplacement drifts.

The maintenance philosophy for underground openings is to have a robust ground support so that maintenance will not be necessary once the waste packages are emplaced. Shafts, ramps, and main drifts, which do not have high temperatures or radiation levels during normal operations, can rely on periodic, planned maintenance.

Design Description

The Ground Control System will consist of the structures installed within the excavated openings or reinforcement made to the rock surrounding the opening. Three ground control systems are under consideration for use in the emplacement drifts. The current design uses precast concrete segments in 90 percent of the emplacement drifts to facilitate installation, provide superior quality control, minimize maintenance requirements, provide for long-term performance, and control costs.

For the remaining 10 percent of the emplacement drifts, rock bolts and mesh supports will be used to allow mapping of these drifts. Cast-in-place concrete linings then will be placed in the emplacement drifts after mapping of rock parameters is completed.

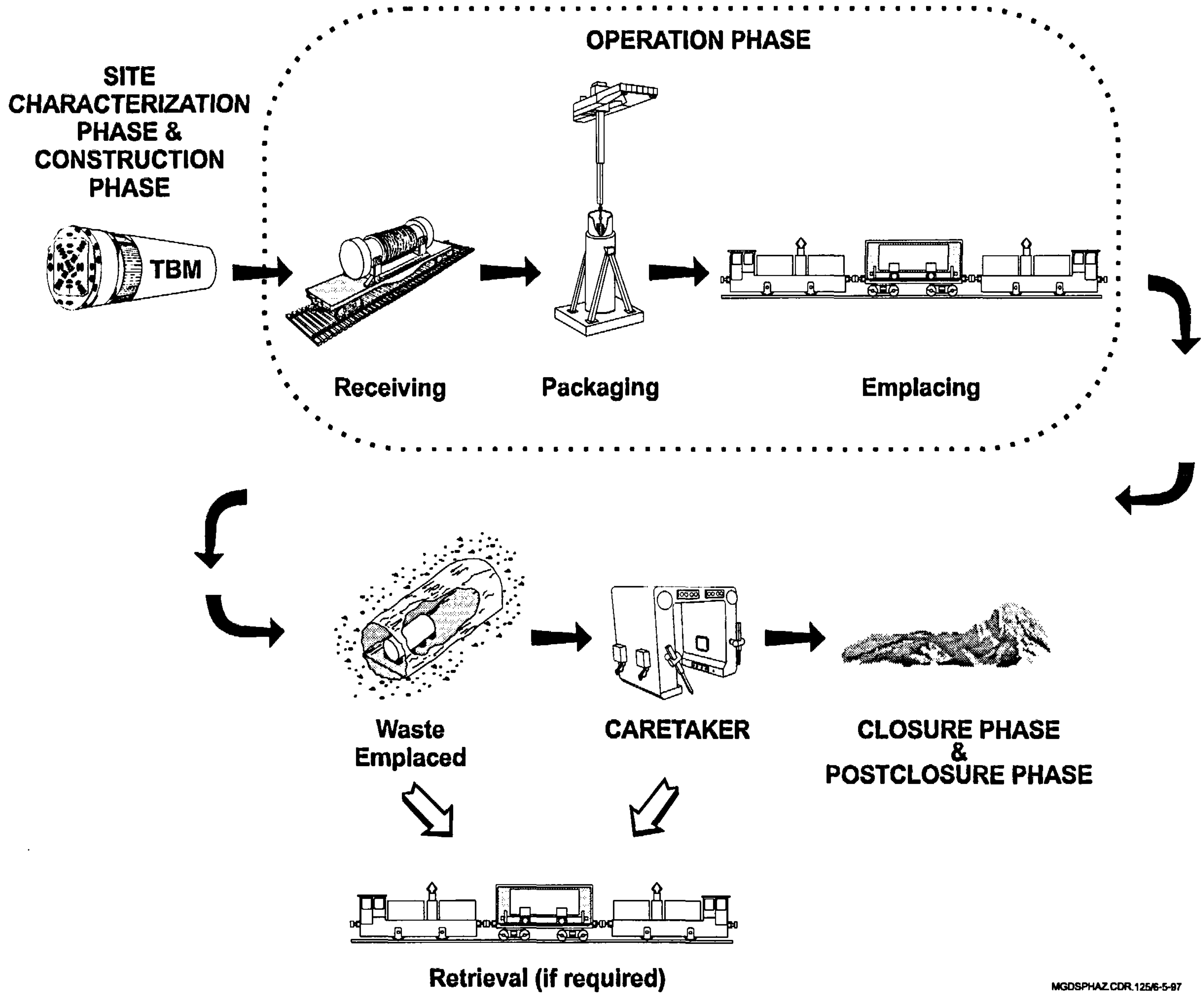
Cast-in-place concrete linings currently are planned for the access ramps and main drifts.

The Ground Control System will be selected and designed to

- provide a robust support system with minimal maintenance requirements;
- maintain stable underground openings, under the range of anticipated conditions, during the operations and caretaker phases, and during decommissioning;
- enhance the potential repository's waste isolation capabilities; and
- facilitate mapping of the rock mass in selected areas.

The reference design for the emplacement drift lining is currently based on a precast concrete lining. However, cast-in-place concrete and steel sets also are being considered for use in the emplacement drifts. In addition, the use of special types of concrete are being evaluated.

Repository Phases



REPOSITORY PHASES OVERVIEW

Six phases comprise the evolution of the potential repository: site characterization, construction, operation, caretaker, closure, and postclosure. This RDD presents design of the key engineering systems for the operation, caretaker, closure, and postclosure phases.

Site Characterization Phase

This phase will include those activities associated with gathering and evaluating data to determine the suitability of the site for a geologic repository; predicting the performance of the repository; preparing the repository designs; and assessing the system performance. The Exploratory Studies Facility which has been constructed will be enhanced as deemed necessary during this phase.

Construction Phase

This phase will include constructing and equipping of surface facilities, refurbishing Exploratory Studies Facility openings, continued excavation and equipping of subsurface facilities, gathering data to support predictions of the repository performance, fabrication of the disposal containers, and demonstration of some of the repository operations.

Operation Phase

Receiving. The potential repository will receive transportation casks by rail or truck loaded with waste. The casks will be moved to the carrier preparation building, removed from their carriers, and moved to the waste handling building.

Packaging. The casks will then be opened and the waste removed. The waste will then be loaded into a disposal container, thus creating a waste package. Next, the waste package will be loaded into a transporter to be taken to the underground emplacement location.

Emplacing. After the transporter is loaded, it will move the waste package from the waste handling building to the emplacement drift. The waste package will then be pushed into the emplacement drift and positioned within the drift using a remotely controlled gantry.

Caretaker Phase

The caretaker phase will begin when all waste packages have been emplaced. This also will include continuing of performance confirmation activities and maintenance of the subsurface facility. The capability to retrieve the waste packages also will be maintained.

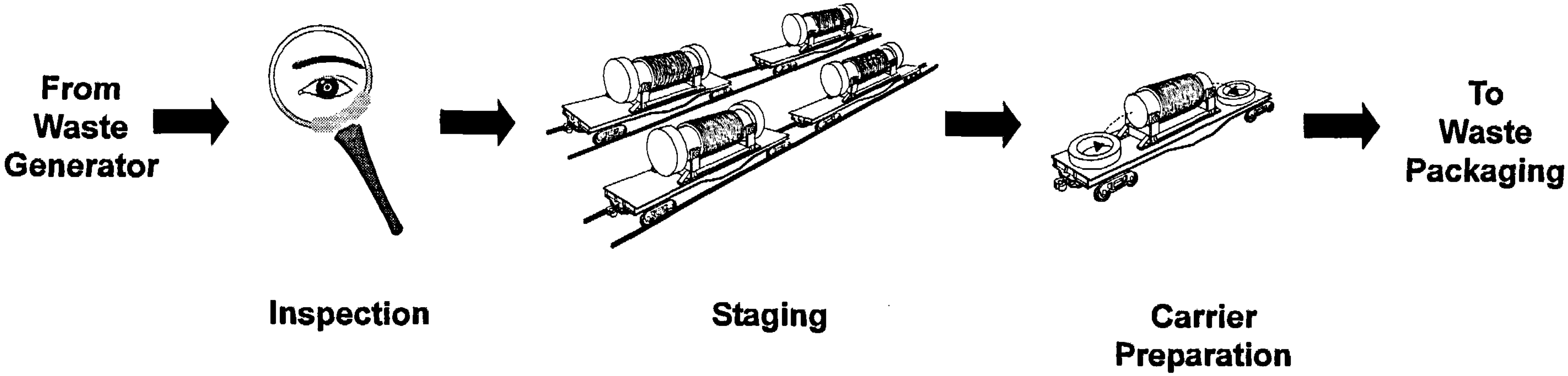
Closure Phase

The closure phase will begin after the license to close the repository has been received from the NRC and caretaker activities have ended. Closure will include placement of backfill, if any, and seals and the dismantlement of the surface facilities

Postclosure Phase

The repository will require no human support during the postclosure phase. The potential repository will continue to isolate the waste for thousands of years.

Waste Receiving Operations



Waste Receiving Operations

The potential repository will receive high-level waste and spent nuclear fuel in shielded shipping casks licensed for nuclear waste transport by the NRC on carriers pulled by locomotives or trucks (prime movers). About 700 casks will be received annually. Rail lines will be provided to the site to support the transportation of large shipping casks. Truck access also will be provided to the site for legal weight trucks and, if necessary, heavy haul trucks.

The shipments will pass through a security station and enter the radiologically controlled area near the North Portal. After inspection, the off-site prime mover will move the shipment to a rail or truck carrier parking area, where the shipment will be inspected for radiological contamination. The off-site prime mover waits in the radiologically controlled area until an empty cask is ready to be transported back to the waste shipper.

Once on site, the Carrier/Cask Transport System will handle the carrier and cask. This system will haul the carrier and cask to the carrier preparation building with the on-site prime mover. The carrier preparation building will be a single-level metal structure with about 20,000 square feet of floor space. The facility will contain the systems and components needed to support the Carrier Preparation Building Materials Handling System. The facility will provide

- staging for eight truck or rail carriers and contains work platforms;
- a 10-ton bridge crane;
- two gantry-mounted manipulators; and
- an office.

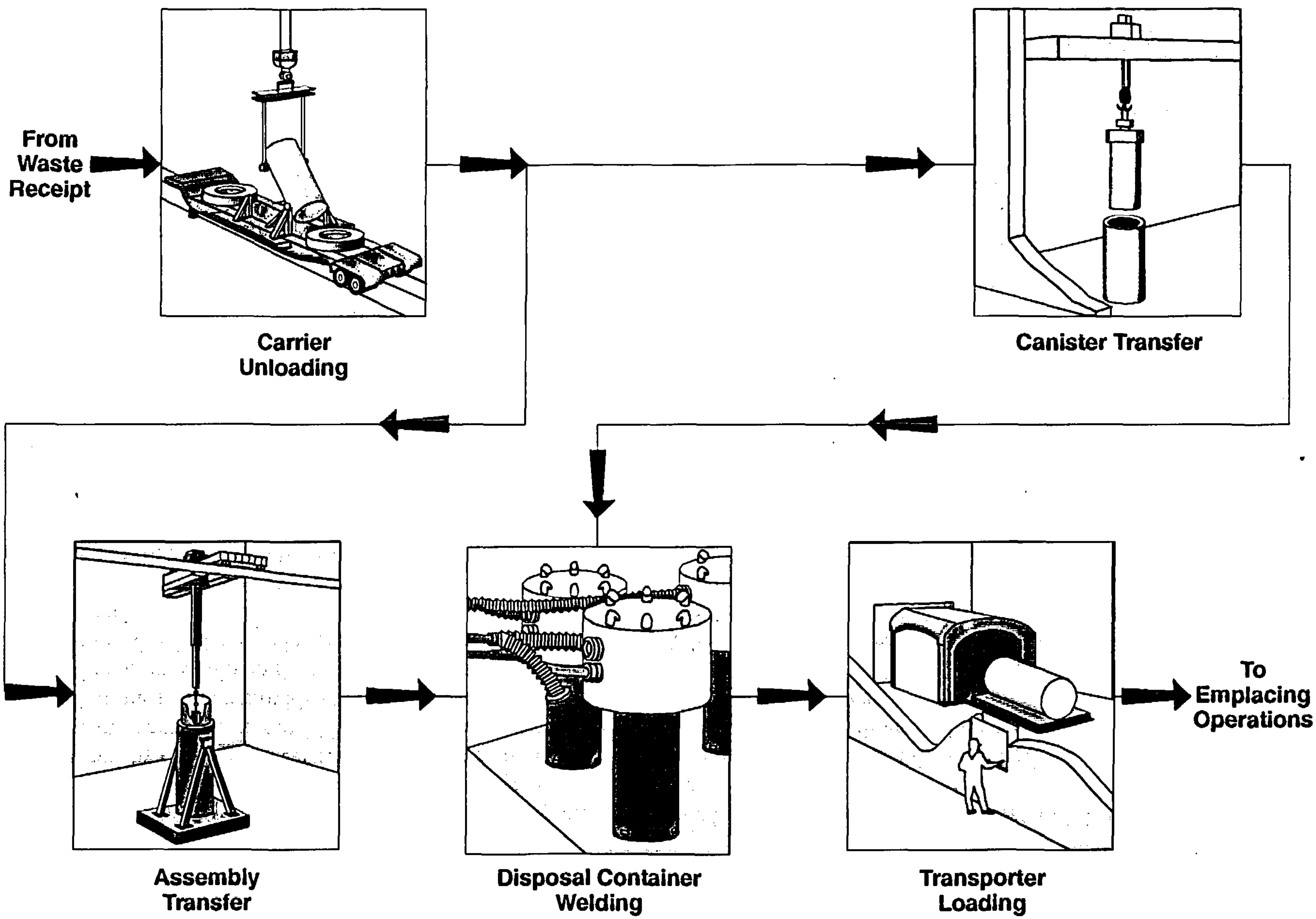
The Carrier Preparation Building Materials Handling System will

- remove or retract the personnel barriers from the cask;
- perform a radiological survey; and
- remove the cask impact limiters.

When the carrier and cask have been prepared for cask removal and the waste handling building is ready to receive a waste shipment, the Carrier/Cask Transport System will haul the carrier and cask with the on-site prime mover to the waste handling building to conduct the waste packaging operations.

After waste removal, the carrier with the empty cask will be hauled back from the waste handling building to the carrier preparation building. The impact limiters and personnel barriers will be reinstalled. The carrier and empty cask will be staged in the carrier parking areas and hauled from the repository by the off-site prime mover.

Waste Packaging Operations



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Waste Packaging Operations

Once the nuclear waste has been received, the loaded shipping casks will be transported to the waste handling building, located in the radiologically controlled area at the North Portal, where the waste will be transferred to disposal containers, sealed closed, and loaded into an underground transporter. These operations will be performed in the waste handling building by the four systems listed below. The waste handling building will house a variety of support systems to provide a secure, controlled environment that protects the workers and confines contamination.

- Carrier/Cask Handling System will remove loaded casks from the truck and rail carriers and place empty casks and dual purpose canisters on carriers. A dual purpose canister will be licensed by the NRC for transportation and dry storage but will not be designed for disposal in the repository.

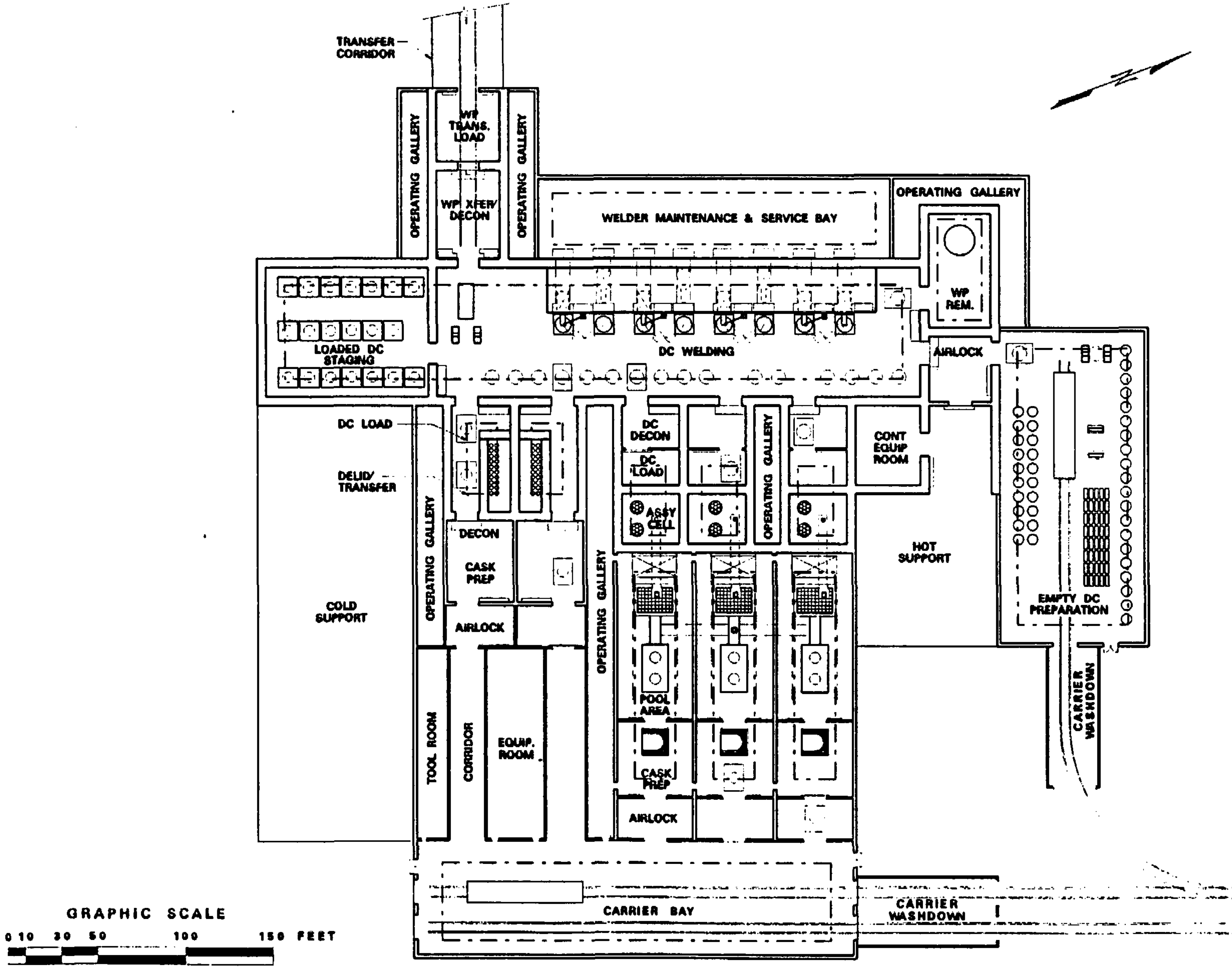
- Assembly Transfer System will receive casks containing uncanistered spent nuclear fuel assemblies or dual purpose canisters, and transfer the assemblies to disposal containers.

- Canister Transfer System will receive casks containing waste in disposable canisters and transfer the canisters to disposal containers.

- Disposal Container Handling System will weld the lids onto disposal containers and load the waste packages (loaded and sealed disposal containers) into a shielded transporter for haulage to the underground emplacement area.

A description of each of these system is provided in later sections of this document.

Waste Handling Building



Waste Handling Building

The waste handling building will provide the structures, systems, and components that support the waste packaging operations including: electrical, security, fire protection, ventilation, communications, and radiological monitoring. The waste handling building will provide a controlled environment for the dry and pool-handling operations. It will serve as a contamination structure to confine contamination and provide radiological protection for personnel and the public.

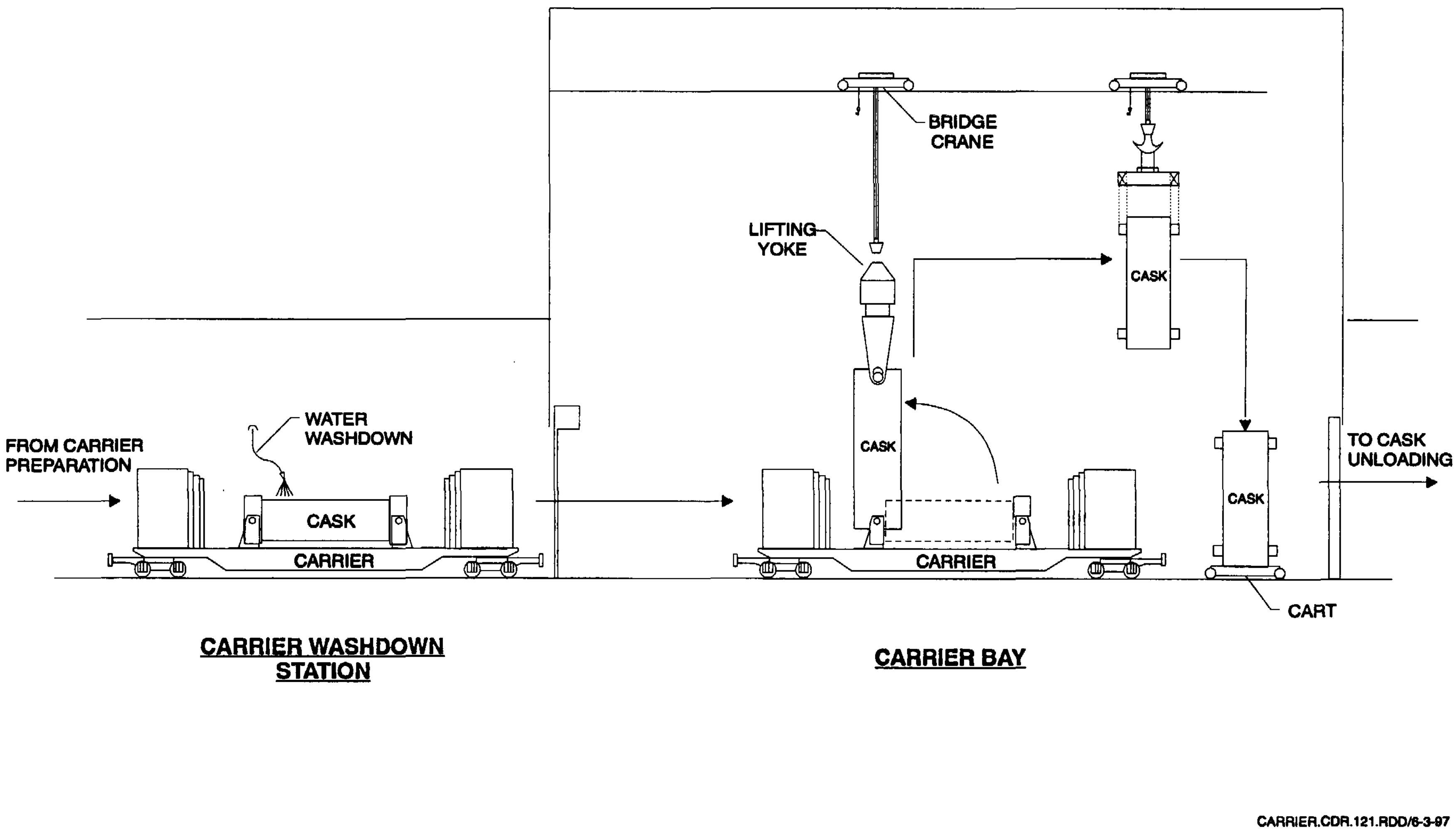
Design Description

The waste handling building will include the waste handling areas, support areas and features described below:

- five-level concrete structure;
- about 480,000 square feet of floor space and a footprint of about 320 feet by 490 feet;
- one large bay for loading and unloading truck and rail carriers;
- three assembly transfer lines, each with pools for unloading and staging assemblies and three hot cells for conducting the other Assembly Transfer System operations;
- two canister transfer lines, each with a cask preparation area and one hot cell for conducting the Canister Transfer System operations;
- one large hot cell for staging and welding disposal containers;
- one small hot cell for placing a loaded disposal container in an underground transporter;
- one general purpose hot cell for mitigating an off-normal disposal container;
- operating galleries to view and control hot cell operations;
- contaminated equipment maintenance area;
- laboratories, mechanical equipment rooms, electrical equipment rooms, and tooling and maintenance store rooms; and
- support areas for administrations, personnel, and central control.

Selected assembly handling operations will be conducted underwater in pools. This approach uses water to shield the workers from direct radiation while providing direct access to the waste forms. Operations in the presence of loaded casks, spent nuclear fuel assemblies, canisters and disposal containers will be conducted remotely in hot cells to protect the workers from direct radiation. The remote equipment will be designed for ease of decontamination and maintenance. Interchangeable components will be provided where appropriate. Semi-automatic and manual controls will control remotely operated equipment.

Carrier/Cask Handling System



Carrier/Cask Handling System

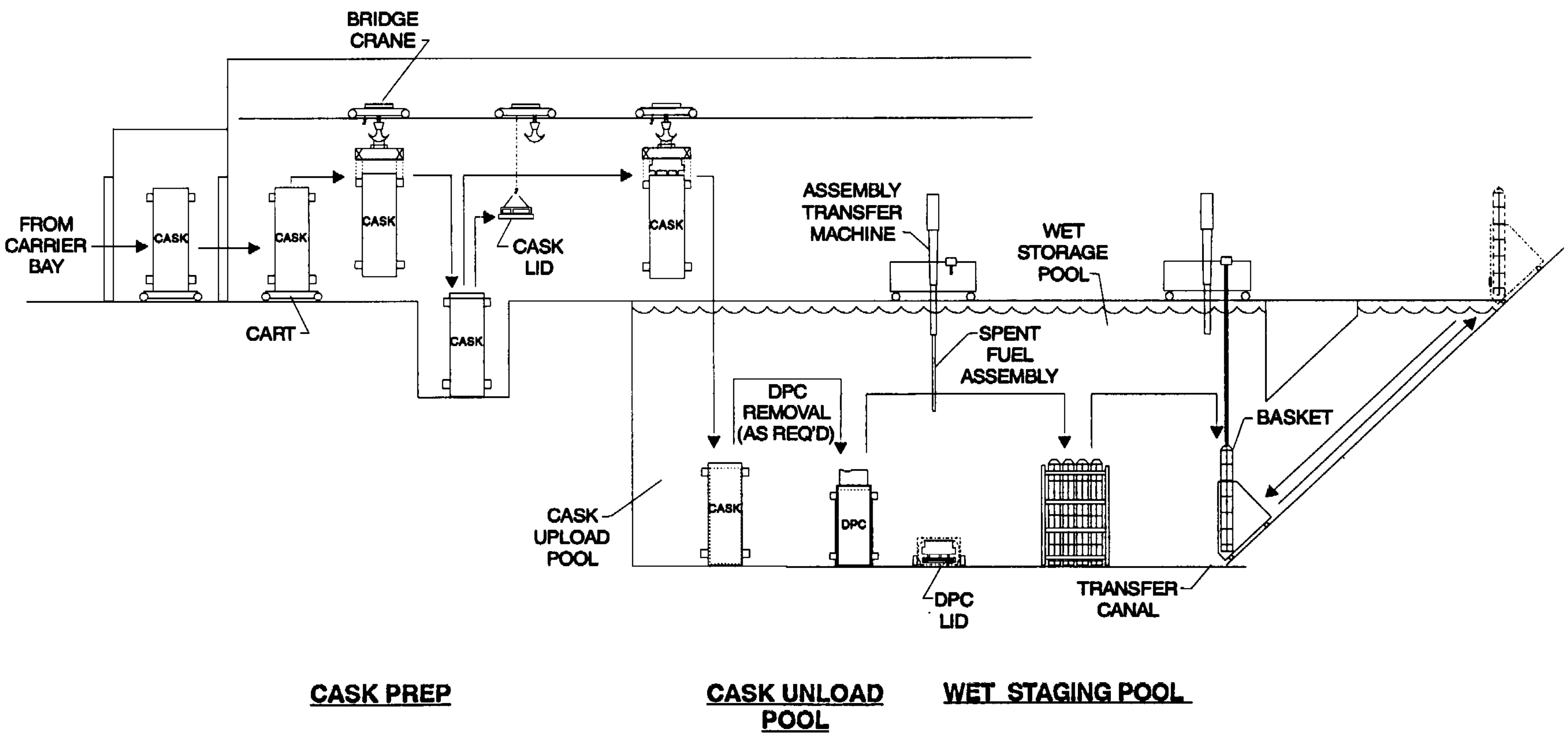
The Carrier/Cask Handling System will remove loaded casks from the truck and rail carriers and place empty casks and dual purpose canisters on carriers for off-site shipment. In a peak year, the system will receive and ship about 700 casks and ship about 400 dual purpose canisters. The system will support the waste packaging operations and will be located in the waste handling building.

Design Description

Operations will begin as a truck or rail carrier is hauled to the waste handling building from the Carrier/Cask Transport System. Prior to entering the building, the impact limiters and personnel barriers will have been removed or retracted. Road grime will be removed in a washing station, then the carrier will be moved into the carrier bay. A large bridge crane on the carrier will lift the cask from a horizontal to a vertical orientation and place it on a transfer cart. The remotely operated cart will move through an airlock into one of the five waste transfer lines. Where possible, operations on loaded casks will be conducted remotely to limit worker exposure to radiation. Empty casks and empty dual purpose canisters will be removed from the waste transfer lines and loaded on the carriers in the reverse sequence. The large, open carrier bay will have the following features:

- two flush-mounted rail spurs;
- a 125-ton bridge crane;
- lifting yoke staging areas; and
- access to the cask carts.

Assembly Transfer System



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Assembly Transfer System

The Assembly Transfer System will receive casks containing uncanistered fuel assemblies and dual purpose canisters and will transfer the assemblies to disposal containers. Empty shipping casks and dual purpose canisters will be prepared for off-site shipment. In a peak year, the system will receive and transfer about 12,000 assemblies from 540 casks into 380 disposal containers. The system will support the waste packaging operations and will be located in the waste handling building.

Design Description

Operations will begin as a vertically loaded shipping cask enters one of the three identical assembly transfer lines from the Carrier/Cask Handling System. The cask, on a remotely operated cart, will pass through an airlock and into a cask preparation area. In the preparation area, a cask containing uncanistered fuel assemblies will be prepared for unloading by sampling the interior gas, venting, cooling, filling the cask with water, and remotely de-tensioning the lid bolts. A large bridge crane then will move the cask into an assembly unloading pool. For casks containing a dual purpose canister, preparation includes removal of the cask lid and preparing the dual purpose canister for unloading by sampling the interior gas, venting, cooling, and filling the dual purpose canister with water. The preparation area will include:

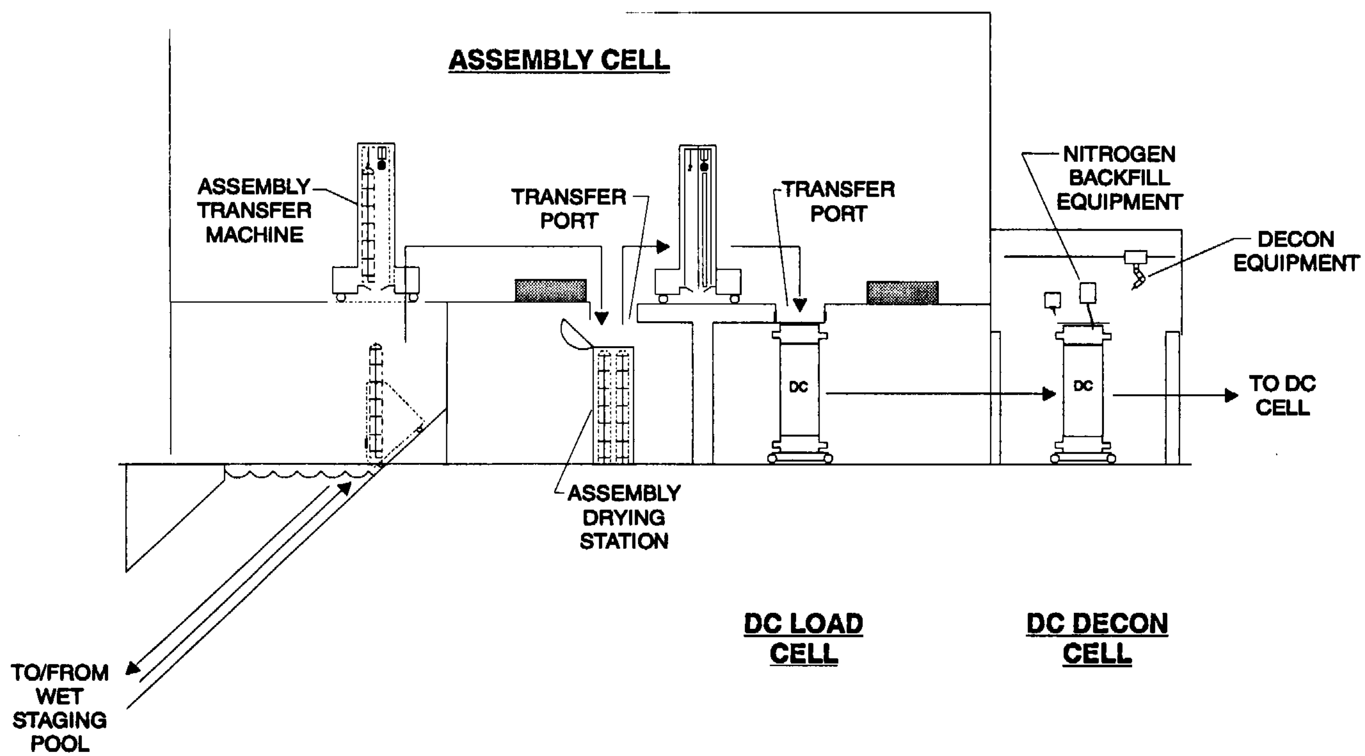
- a preparation pit;
- manipulator;
- a preparation manifold;
- decontamination equipment; and
- a 125-ton bridge crane that is shared with the pool area.

The decontamination equipment will be used after waste transfer to prepare empty casks and dual purpose canisters for shipment.

In the pool, depending on the cask type, either the cask lid will be removed, or the dual purpose canister will be unloaded from the cask with the bridge crane and the dual purpose canister lid will be cut off. The exposed assemblies will be transferred with a fuel-handling machine to a staging rack or directly to an underwater transfer cart. The cart will transfer the assemblies through a canal to the assembly hot cell. The empty cask will be transferred to a preparation area for dewatering and decontamination. The empty dual purpose canister will be internally cleaned and dewatered in the pool area and transferred to the preparation area for over packing and decontamination. The pool area includes:

- the unloading and staging pools;
- a 125-ton bridge crane;
- a wet fuel transfer machine;
- staging racks for about 240 to 540 assemblies;
- dual purpose canister cutting tools;
- a wet cleaning system;
- an underwater assembly transfer cart; and
- underwater cameras.

Assembly Transfer System (cont'd)



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Assembly Transfer System (cont'd)

In the assembly hot cell, a vacuum system will dry the assemblies , which will then be transferred to an empty disposal container with a dry-fuel-handling machine. During the transfer, the disposal container will be mated to the assembly hot cell through a transfer port to limit the spread of airborne contamination. All operations will be conducted remotely. The assembly hot cell will include:

- the dry-fuel-handling machine;
- a mating port system;
- two vacuum drying vessels;
- five-foot thick shield walls;
- cameras; and
- shield windows.

The cell also will have:

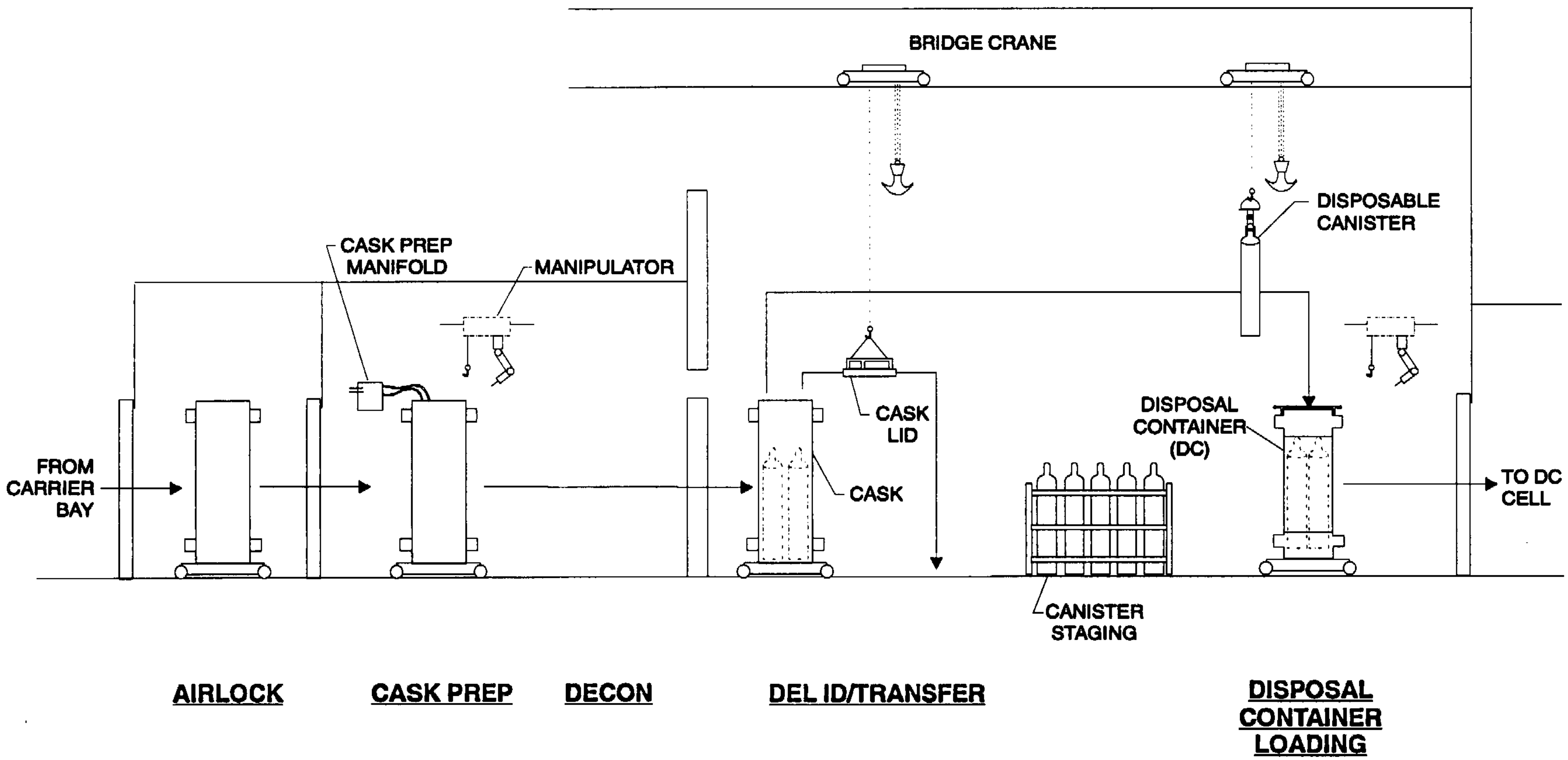
- a bridge crane;
- manipulator; and
- maintenance bay to support maintenance and repair.

A disposal container loading and decontamination hot cell will be located below the transfer port. In this cell, the loaded disposal container will be temporarily lidded, disengaged from the port, and transferred on a cart to a decontamination station.

The disposal container will be decontaminated, filled with nitrogen, and transferred to the Disposal Container Handling System for sealing. All operations will be conducted remotely. The disposal container loading and decontamination cell will include:

- a disposal container transfer cart;
- decontamination system;
- manipulator;
- nitrogen addition system;
- five-foot thick shield walls;
- cameras; and
- shield windows.

Canister Transfer System



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Canister Transfer System

The Canister Transfer System will receive casks containing waste in disposable canisters and transfer the canisters to disposal containers. Empty shipping casks will be prepared for off site shipment. In a peak year, the system will receive transfers of about 800 small canisters (e.g., vitrified defense high-level waste) from 160 casks into 200 disposal containers and has the capability to transfer about 300 large canisters (e.g., multi-purpose canisters). The system will support the waste packaging operations and will be located in the waste handling building.

Design Description

Operations will begin as a vertically loaded shipping cask enters one of the two identical canister transfer lines from the Carrier/Cask Handling System. The cask, on a remotely operated cart, will pass through an airlock and into a cask preparation and decontamination area. In this area, a cask containing a disposable canister will be prepared for unloading by sampling the interior gas, venting, and remotely de-tensioning the lid bolts. A cart will move the prepared cask into a hot cell. Operations on a loaded cask generally will be conducted remotely. The preparation and decontamination area will include:

- a cask transfer cart;
- a cask prep manipulator;
- a cask sampling/venting system;
- decontamination equipment;
- cameras; and
- shield windows.

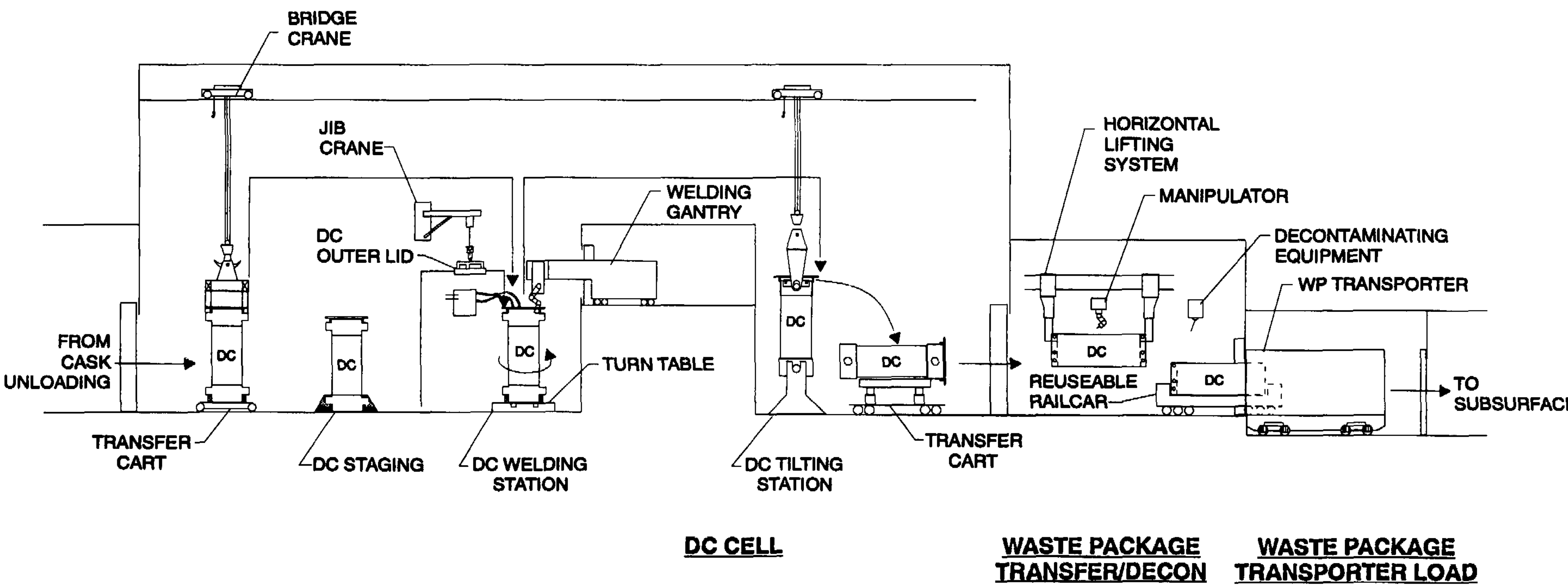
The decontamination equipment will prepare empty casks for shipment after waste transfer.

In the hot cell, the cask lid will be removed and the canister(s) will be lifted from the cask. A large canister will be loaded directly into a disposal container. Small canisters will be loaded directly into a disposal container or will be accumulated in a staging rack until enough compatible canisters are available to fill a disposal container. The loaded disposal container will be transferred to the Disposal Container Handling System on a cart for sealing. All operations will be conducted remotely. The hot cell will include:

- an 85-ton bridge crane;
- a disposal container loading manipulator;
- a staging rack for about 15 small canisters;
- various lifting fixtures;
- a disposal container transfer cart;
- five-foot thick shield walls;
- cameras; and
- shield windows.

A crane maintenance bay will support maintenance and repair operations.

Disposal Container Handling System



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Disposal Container Handling System

The Disposal Container Handling System will weld the lids on the loaded disposal containers and load the disposal containers into a shielded transporter for hauling to the underground emplacement area. The system will provide empty (new) disposal containers to the waste assembly lines. In a peak year, the system will receive, seal, and ship about 580 disposal containers. The system will support the waste packaging operations and be located in the waste handling building.

Design Description

Operations will begin as a vertically loaded disposal container enters the disposal container cell from one of the five waste transfer lines (i.e., from the Assembly Transfer System or the Canister Transfer System). The disposal container will be on a remotely operated cart and moved to within the reach of a large bridge crane. The crane will move the disposal container to a staging fixture or directly to a welding station. At the welding station, the inner lid will be welded on and inspected, and the disposal container will be filled with helium, The outer lid will be welded on and inspected. The robotic welder will be mounted on a movable boom that can be withdrawn through the cell wall and into a maintenance bay. The disposal container will rotate during welding.

The sealed and loaded disposal container will be lifted from the weld station and placed in a staging fixture or directly in a tilting fixture. At the tilting fixture, a crane will lay the disposal container onto a transfer cart. The cart will transfer the disposal container from the disposal container cell to a disposal container transfer and decontamination hot cell. All disposal container cell operations will be conducted remotely. The disposal container cell will include:

- an 85-ton bridge crane;
- about eight welding stations;
- four jib cranes to support the welders;
- about 20 disposal container staging fixtures;
- six vertical disposal container transfer carts (five for the transfer lines, one for empty disposal container);
- a horizontal transfer car;
- tilting fixture;
- a manipulator;
- various lifting yokes;
- five-foot thick shield walls;
- cameras; and
- shield windows.

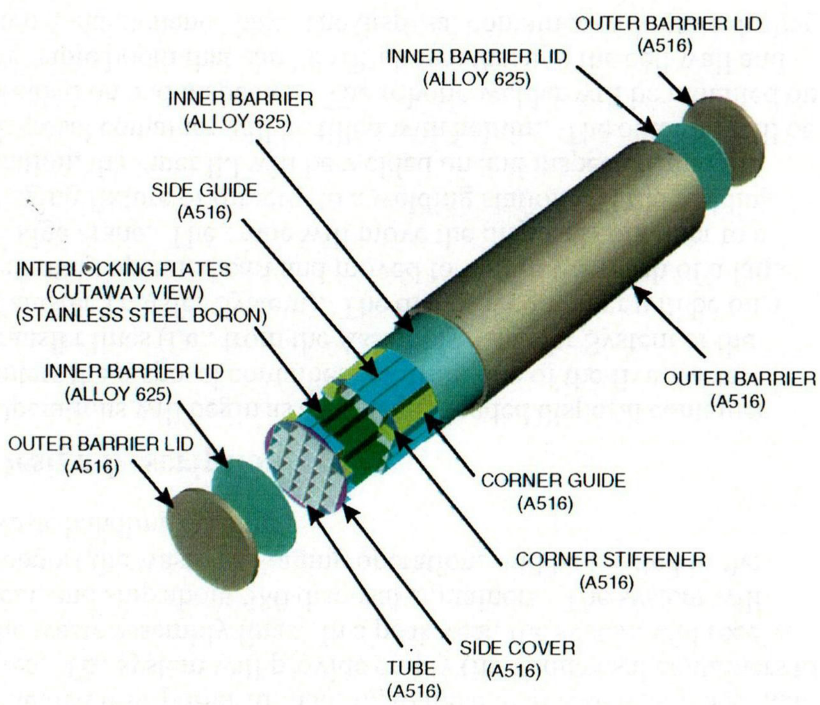
The cell will have a crane maintenance bay to support maintenance and repair operations.

In the disposal container transfer and decontamination hot cell, an overhead lifting system will lift the disposal container from the cart and the cart will be returned to the disposal container cell. While suspended, the disposal container will be decontaminated as needed. A railcar will be pushed under the disposal container from the underground transporter. The disposal container will be lowered onto the railcar and the loaded railcar pulled back into the transporter. The shielded transporter will leave the waste handling building to complete the waste packaging operations. All disposal container transfer and decontamination cell operations will be conducted remotely. This cell will include:

- an 80 ton large lifting system;
- decontamination equipment;
- a manipulator;
- a horizontal transfer cart;
- five-foot thick shield walls;
- cameras; and
- shield windows.

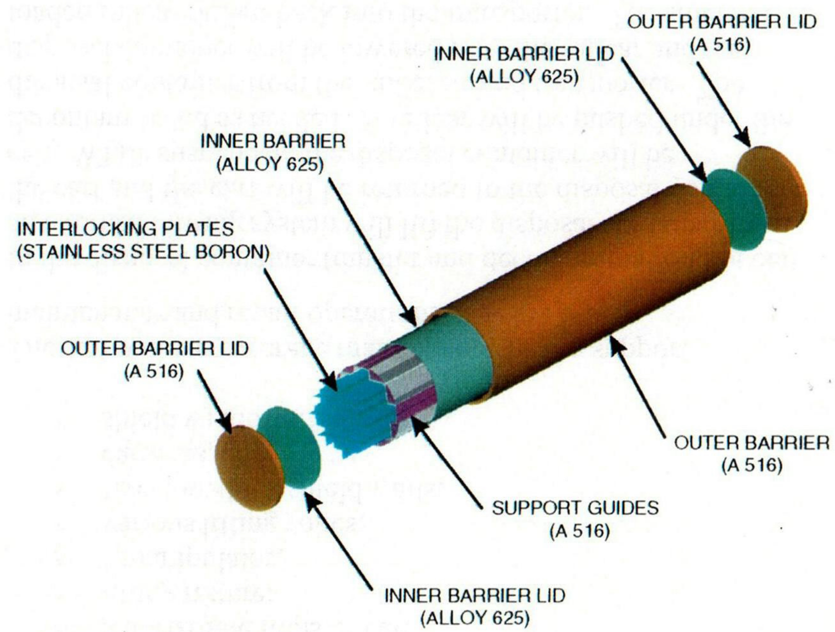
Spent Nuclear Fuel Disposal Containers

21-PWR UNCANISTERED FUEL DISPOSAL CONTAINER ASSEMBLY



LENGTH = 5335 mm
DIAMETER = 1650 mm
TARE WEIGHT = 34,039 kg
LOADED WEIGHT = 50,423 kg

44-BWR UNCANISTERED FUEL DISPOSAL CONTAINER ASSEMBLY



LENGTH = 5335 mm
DIAMETER = 1604 mm
TARE WEIGHT = 31856 kg
LOADED WEIGHT = 46424 kg

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Spent Nuclear Fuel Disposal Containers

The spent nuclear fuel disposal containers have been designed to hold bare spent nuclear fuel assemblies. The disposal containers will support the confinement and isolation of waste within the potential geologic repository. The spent nuclear fuel disposal containers will be loaded with spent nuclear fuel assemblies from either boiling water reactors (BWRs) or pressurized water reactors (PWRs).

Design Description

Two BWR and three PWR disposal container designs will be developed to provide long-term confinement of the commercial spent nuclear fuel; the dimensions for each are shown in the table below.

Waste Package Type	Outer Diameter	Outer Length	Outer Barrier Thickness	Inner Barrier Thickness
21 PWR	1.65 m	5.34 m	0.10 m	0.02 m
12 PWR	1.30 m	5.34 m	0.10 m	0.02 m
12 PWR	1.30 m	5.86 m	0.10 m	0.02 m
44 BWR	1.60 m	5.34 m	0.10 m	0.02 m
24 BWR	1.27 m	5.34 m	0.10 m	0.02 m

These disposal containers will be designed to hold as much spent nuclear fuel as possible without exceeding the physical limits placed on the containers. The corrosion-resistant inner barrier will be constructed of a high-nickel steel (Alloy 625) and the corrosion-allowance outer barrier will be made of carbon steel (Alloy A516). The two metal barriers will support the design philosophy of using materials with different failure mechanisms to protect against the release of radioactive materials.

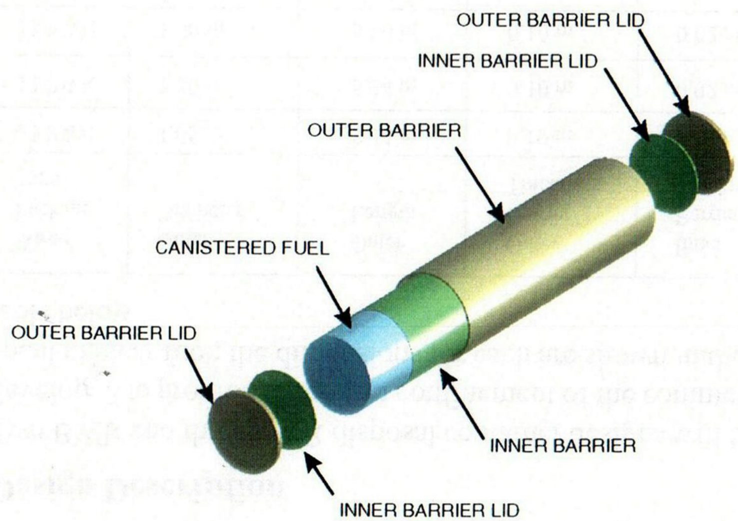
An internal metallic structure, a basket, will hold the spent nuclear fuel assemblies. The basket will provide for criticality control, structural support, and heat conduction paths to cool the spent nuclear fuel. Neutron absorbers also can be used to control criticality, if water were to flood the disposal container.

The 21 PWR disposal container will use a basket either with or without neutron-absorber plates, depending upon the reactivity of the spent nuclear fuel . In addition, neutron-absorber rods will be inserted in PWR fuel assemblies as needed for reactivity control. The 12 PWR disposal container will come in two lengths. The shorter (5.34m) 12 PWR disposal container can be used without a neutron absorber, and the longer disposal container (5.86m) can be used with neutron-absorber plates for South Texas spent nuclear fuel assemblies that are significantly longer than other PWR assemblies. The 44 BWR container will be used without neutron absorbers or with neutron-absorber plates. The 24 BWR container will use thicker neutron-absorber plates to control reactivity.

The 24 BWR and 12 PWR disposal containers also will be used for those spent nuclear fuel assemblies with a heat-output level above the reference design levels.

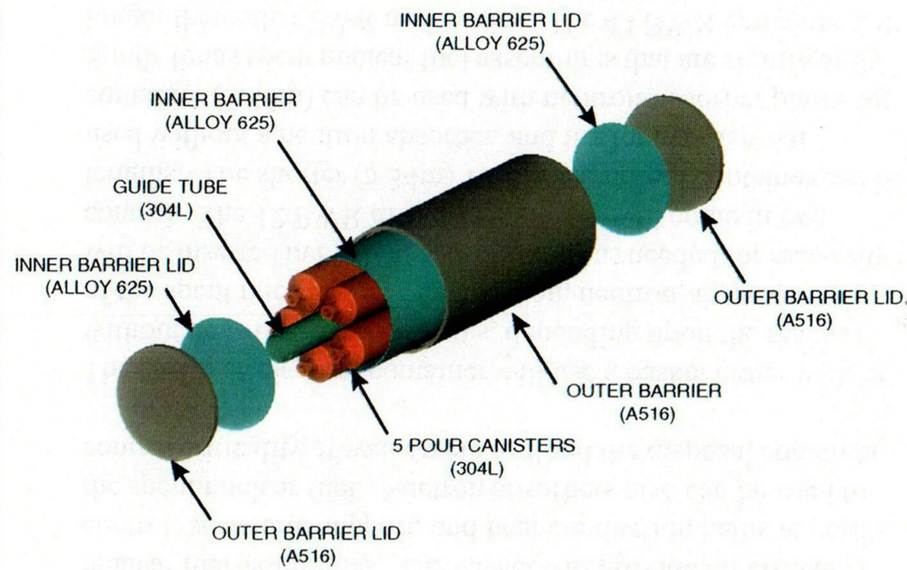
Canistered Waste Disposal Containers

CANISTERED FUEL-WASTE PACKAGE ASSEMBLY 21-PWR / 40-BWR



LENGTH = 5682 mm
DIAMETER = 1802 mm
TARE WEIGHT = 31,176 kg
LOADED WEIGHT = 65,900 kg (PWR)
LOADED WEIGHT = 65,463 kg (BWR)

5 DHLW WASTE PACKAGE ASSEMBLY



LENGTH = 3790 mm
DIAMETER = 1970 mm
TARE WEIGHT = 24,782 kg
LOADED WEIGHT = 35,692 kg

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Canistered Waste Disposal Containers

The canistered waste disposal containers will be used for direct disposal of either canistered spent nuclear fuel or high-level waste. Canistered waste disposal containers also will be designed for the co-disposal of DOE spent nuclear fuel and high-level waste. The disposal containers will support the containment and isolation of canistered waste within the engineered barrier of the potential repository. Disposable canisters filled with spent nuclear fuel or high-level waste will be loaded and sealed in the canistered waste disposal containers in the waste handling building.

Design Description

The canistered spent nuclear fuel disposal containers for direct disposal will come in two sizes. The large disposal container will hold one large disposable canister of spent nuclear fuel with either 21 PWR or 40 BWR assemblies. The small disposal container will hold one small disposable canister of spent nuclear fuel with either 12 PWR or 24 BWR assemblies. Direct disposal containers for DOE spent nuclear fuel or Navy spent nuclear fuel are currently being designed.

The high-level waste disposal container for direct disposal will hold five high-level waste canisters. The disposable canister dimensions will be based on the defense waste processing facility canisters from the Savannah River Site. A canister guide of carbon steel (Alloy A516) will be installed in the center of the disposal container's bottom lid. This guide serves to properly place the five canisters within the disposal container.

The co-disposal container for DOE or Navy spent nuclear fuel and high-level waste disposable canisters will hold five high-level waste disposable canisters and a DOE or Navy spent nuclear fuel disposable canister will be inserted in the middle of the high-level waste disposable canisters. The DOE or Navy spent nuclear fuel disposable canister will be inserted in the guide tube depicted in the figure above.

The disposal container characteristics are as follows:

Canistered spent nuclear fuel disposal container

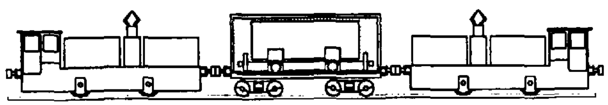
- outer length of either 5.68 (large disposal container) or 5.65 (small disposal container) meters;
- outer diameter of either 1.80 (large) or 1.53 (small) meters;
- 0.10 meter thick, carbon steel (Alloy A516) corrosion-allowance outer barrier; and
- 0.020 meter thick, corrosion-resistant inner barrier of high-nickel steel (Alloy 625).

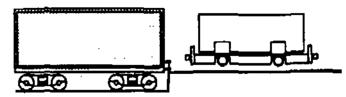
High-level waste disposal container

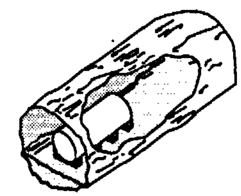
- outer length of 3.79 meters;
- outer diameter of 1.79 meters;
- 0.10 meter thick, carbon steel (Alloy A516) corrosion-allowance outer barrier; and
- 0.02 meter thick, corrosion-resistant inner barrier of high-nickel steel (Alloy 625).

Waste Emplacing Operations

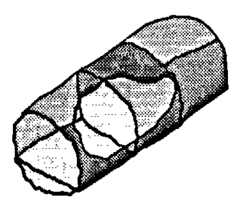
Underground Haulage → **Emplacement** → **Monitoring and Performance Confirmation**



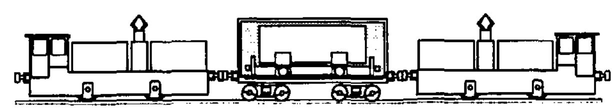




Sealing and Backfill



Retrieval



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Waste Emplacing Operations

Waste Emplacing Operations will consist of five steps:

- transferring the waste underground (see the Waste Emplacement System);
- emplacing the waste in the emplacement drift (see the Waste Emplacement System);
- conducting monitoring and performance confirmation activities (see Performance Confirmation);
- backfilling the emplacement drift, if required; and
- retrieving the waste packages, if required.

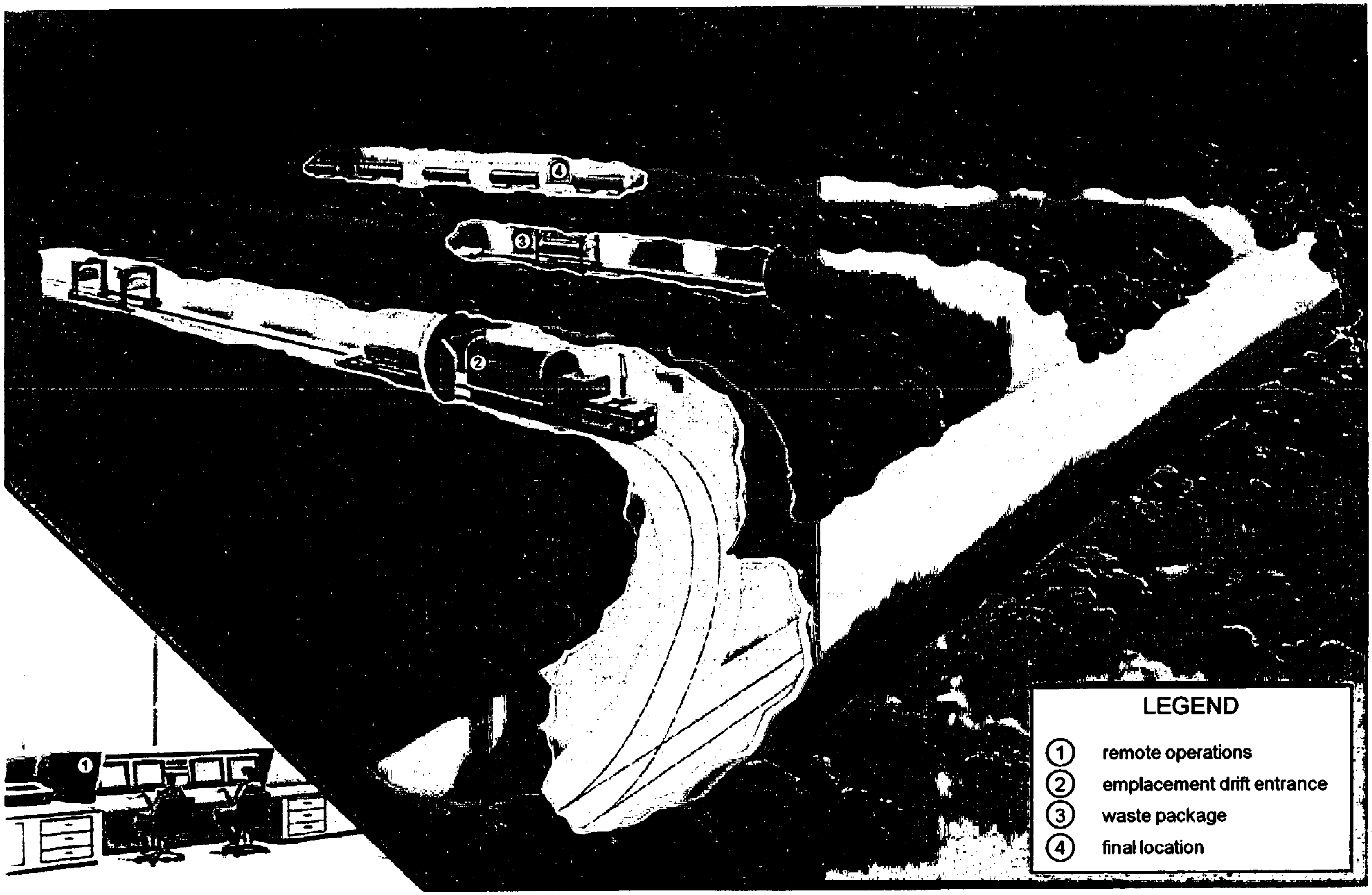
Backfilling of the emplacement drifts is not currently planned. However, flexibility will be included in the design so that backfilling will not be precluded. The option to backfill the emplacement drifts is discussed in the Design Options section of this document.

Retrieval may be required at any time during or after emplacement. The option to retrieve will be in place for 50 years from the start of emplacement. At the end of this retrievability period, a decision may be made to close the repository. If a decision is made to retrieve the waste packages, they will be removed from the emplacement drift by following the emplacement steps in reverse order after first cooling down the emplacement drift with forced ventilation..

Remote inspection of the emplacement drift to identify potential obstructions and removal or shifting of other waste packages may be required for retrieval operations.

Assuming an expected planning period of 10 years, the elapsed time from the order to accomplish full retrieval until the last waste package is on the surface would be 34 years. This retrieval period is for the reference design, with no backfill in the emplacement drifts and under normal conditions.

Waste Emplacement System



Waste Emplacement System

The Waste Emplacement System will transport the loaded and sealed waste package from the waste handling building to the area of emplacement. The system will transport the waste package to the emplacement area and unload the waste package into the emplacement drift.

Design Description

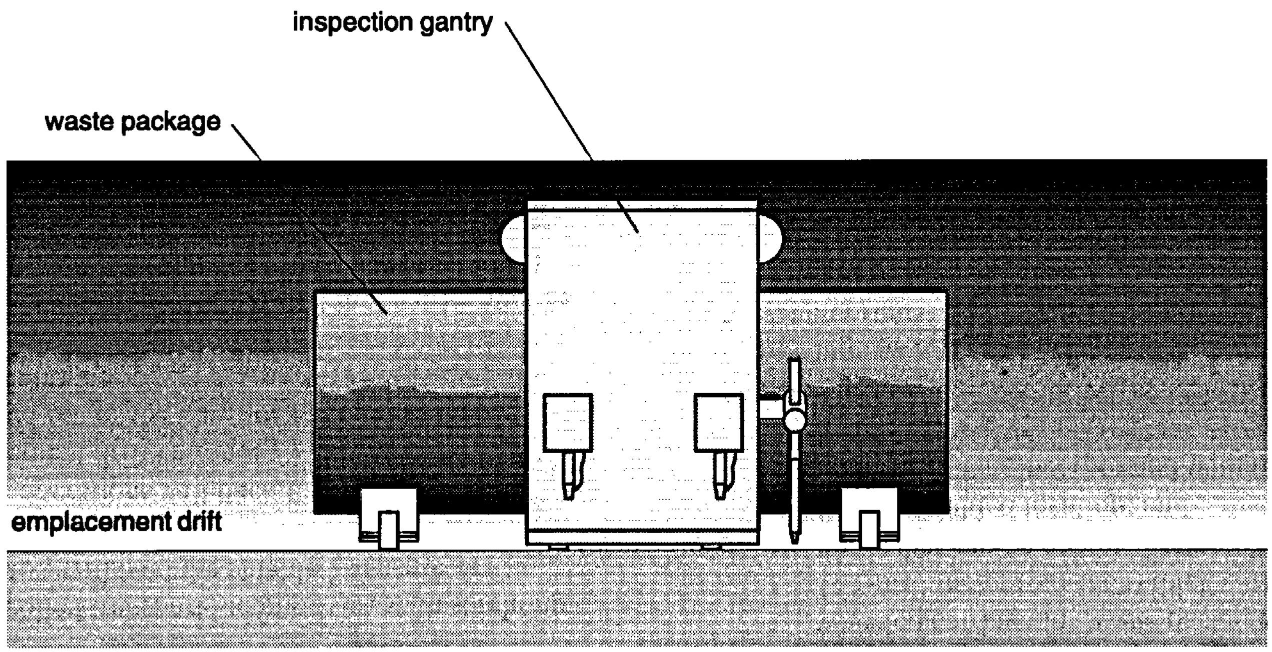
Two manually controlled transport locomotives, with shielding to protect the operator, will haul the shielded transporter containing the waste package down the main drift. Using one locomotive, remote operations will back the transporter into place at the emplacement drift entrance. The waste package will then be unloaded out of the transporter and into the emplacement drift entrance.

The emplacement gantry, already positioned in the drift, will be moved into position over the waste package. The gantry will lift the waste package off the transporter carriage and carry the waste package along the drift to its final location. The gantry will lower the waste package onto its supports and return to the emplacement drift entrance to wait for the arrival of another waste package.

The following equipment will be used to emplace waste.

- Two transport locomotives with the following features:
  - electrically powered (with rails);
  - manually or remotely operated;
  - approximately 600 horsepower locomotive; and
  - weight of 40 metric tons (44 tons) each.
- Transporter with the following features:
  - weight of 150 metric tons (165 tons) empty;
  - weight of 225 metric tons (248 tons) loaded;
  - an integral loading/unloading mechanism to accept and deploy waste packages (includes a wheeled carriage for waste packages);
  - 165-millimeter (6.5-inch) thick carbon steel walls ;
  - doors that can be operated remotely or manually from a shielded location; and
  - braking system incorporated with transport locomotive .
- Gantry transfer locomotive (electrically powered, rail locomotive)
- Gantry transfer flatcar
- Remotely operated gantry.

Caretaker Phase

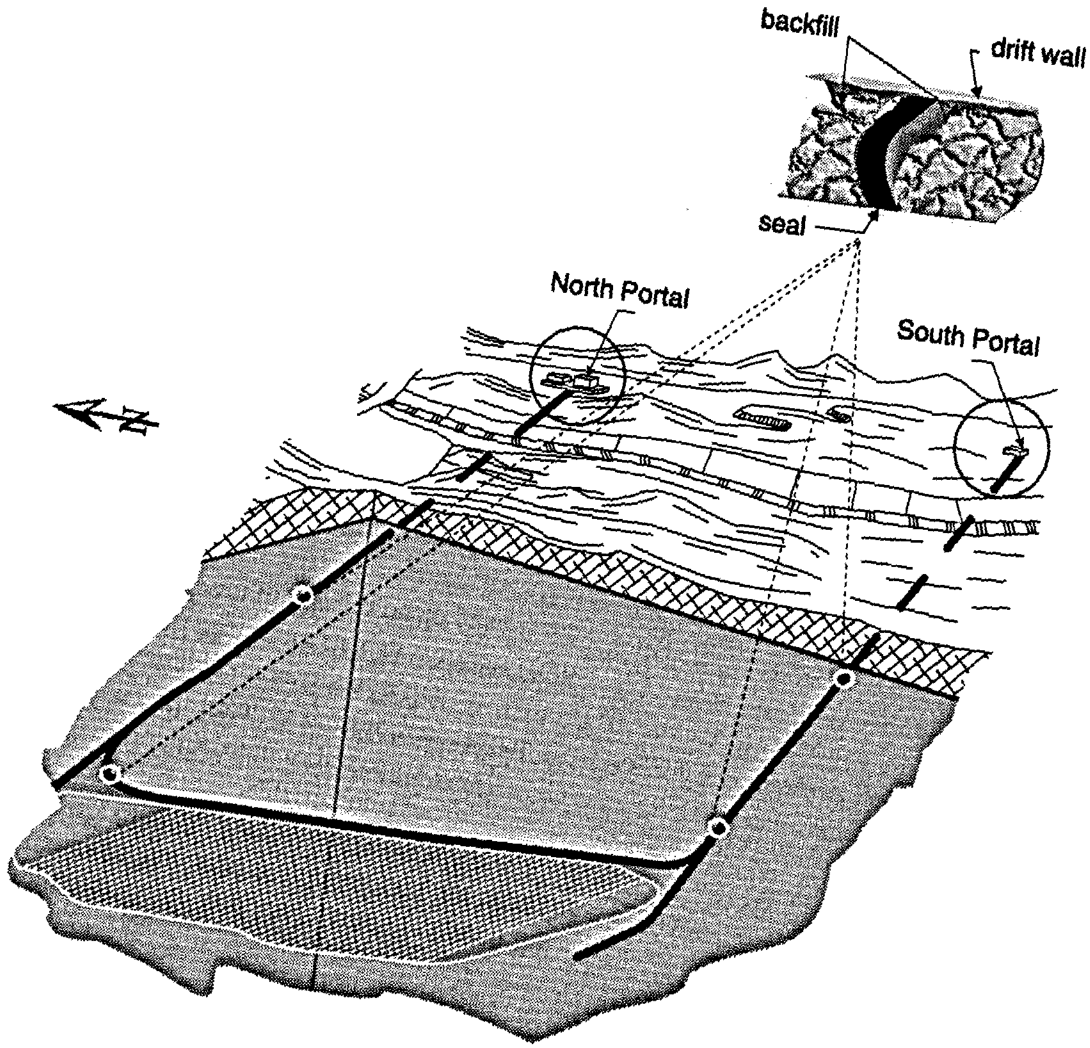


Caretaker Phase

The repository will be monitored and maintained between the time the last waste package has been emplaced and the time the repository is permanently closed. Permanently installed sensors will monitor waste packages, drifts, and the surrounding rock and provide the data required by the performance confirmation activities. A remotely operated inspection gantry will investigate conditions in the emplacement drifts. This will eliminate risk to workers from heat and radiation emanating from the waste packages.

Specific facilities and equipment will be maintained to support the performance activities. Facilities and equipment needed to respond to emergencies and treat low-level waste also will be maintained. Planning and preparation will be conducted during this time in anticipation of closing the repository.

Closure Phase



Closure and Postclosure Phases

Closure

After emplacement of the nuclear waste inventory has been completed and it has been determined that the repository will perform as expected, the repository will be closed permanently. Closure of the repository will consist of four primary missions:

- sealing all openings;
- dismantling the surface facilities;
- restoring the surface area; and
- protecting the repository from unauthorized intrusion.

The sealing of all repository openings will discourage human intrusion and retard the flow of water and gas into and out of the closed facility through engineered openings. Sealing will be accomplished by

- removing all nonpermanent equipment from the subsurface facility;
- placing backfill in the main drifts, shafts, and ramps; and
- installing seals in all openings to the surface, including shafts, ramps, and any boreholes that have been drilled to the repository level.

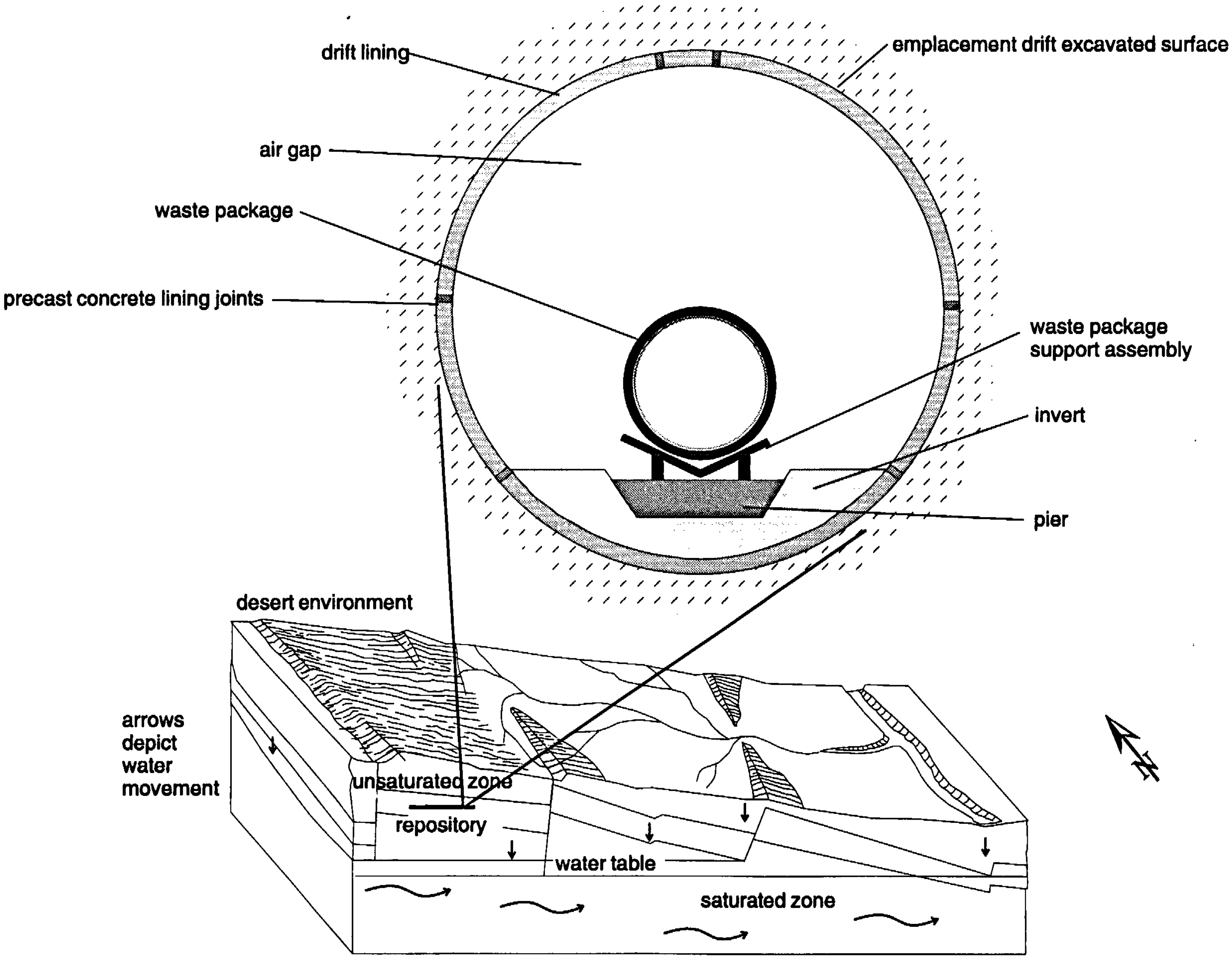
In addition, the surface facilities will be decontaminated and decommissioned during the closure period to restore the site to near its prerepository condition to the extent reasonable and feasible. To facilitate this process, the surface facilities will be designed to simplify final decontamination and decommissioning. During this time, the waste treatment building will provide solid and liquid low-level waste treatment and packaging for transport to low-level waste disposal sites.

Detailed records and information on the repository will be distributed to government organizations. Permanent monuments also will be put in place at the closed repository.

Postclosure

During postclosure, the government will use the detailed records and information supplied during closure as well as legal means—such as laws, permits, and zoning—to control access to the site, thus creating institutional barriers. In addition, fences and warning signs will be maintained.

Waste Isolation



WASTE ISOLATION

The primary mission of the potential repository is the containment and isolation of the waste. This mission will be accomplished by integrating the data collection, design, analysis, and modeling capabilities of the scientific, design, and performance assessment disciplines to define or develop three key systems:

- the Natural Barrier System;
- the Engineered Barrier System; and
- the Performance Confirmation System.

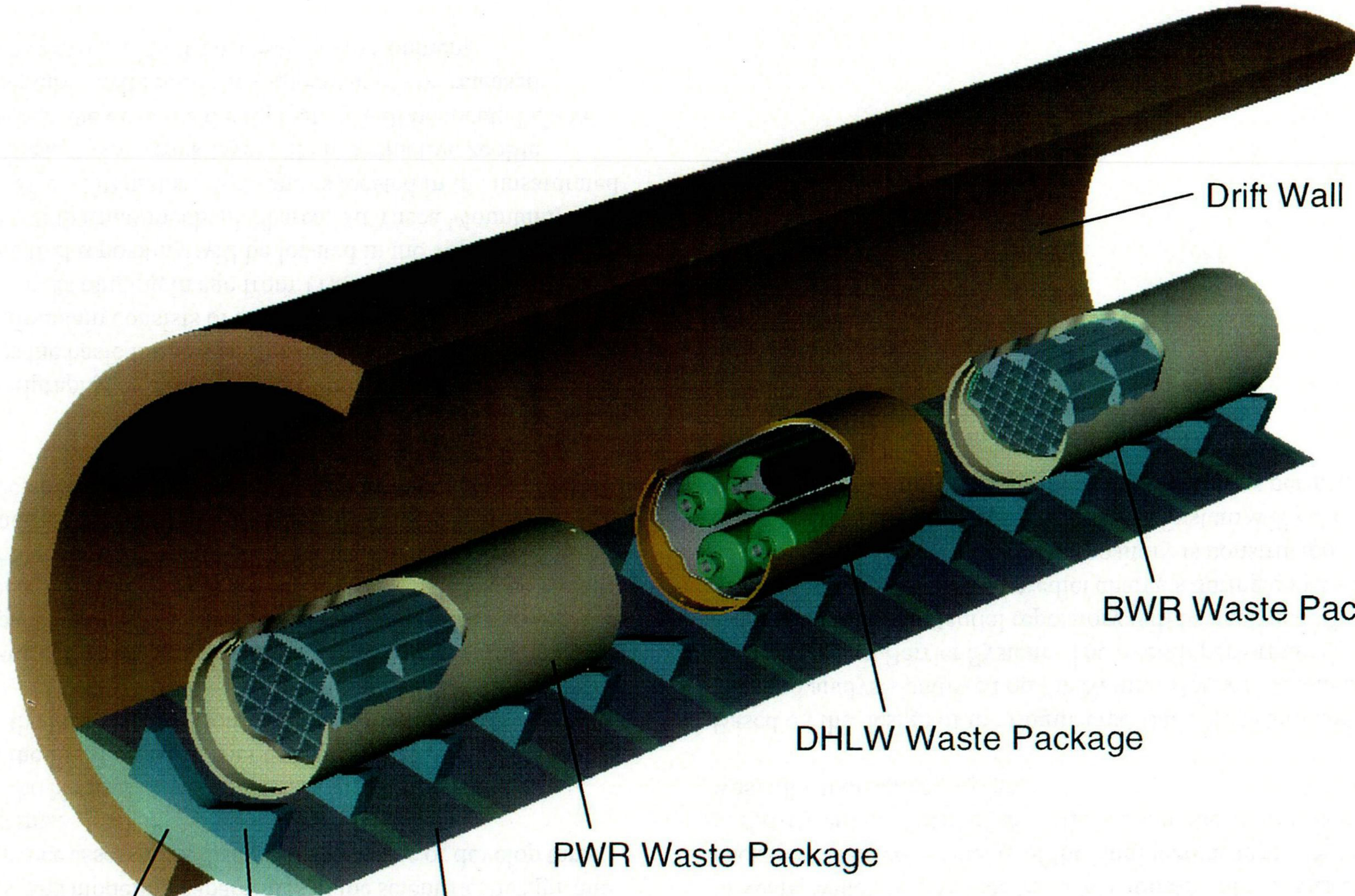
The Natural Barrier System will isolate the waste after the waste packages eventually corrode and deteriorate and the Engineered Barrier System's function is degraded. The Natural Barrier System will consist of the natural environment surrounding the potential repository. This includes the geologic, mechanical, chemical, and hydrological properties of the site.

The stratigraphy, or overall description of the rock layers, provides the basic framework for the Natural Barrier System. Yucca Mountain consists of several thousand meters of layered volcanic tuffs ranging in age from 11.5 to 15 million years old. The potential repository will be located in the Topopah Spring welded tuff thermal/mechanical area. At Yucca Mountain, this unit is 180 to 230 meters thick and is located in the unsaturated zone. These various rock layers, their distinctive zeolite content, and the distance the repository will be located above the water table will retard the movement of any released radioactive material to the accessible environment.

The Engineered Barrier System will provide the first means of containment for the waste. The heat from the waste packages will keep the rock immediately around the drift dry for hundreds of years, which will reduce the corrosion rate of the waste packages. The components of the Engineered Barrier System, in the dry environment of the drift, are intended to contain the waste for thousands of years.

Based on the design of the Engineered Barrier System and the data and analysis gathered on the Natural Barrier System and the Engineered Barrier System. The overall performance assessment of the potential repository will be analyzed. This information will be used to predict changes during construction and operation. As the potential repository is constructed and operated, the Performance Confirmation System will perform confirmation testing to verify that the repository is performing as anticipated.

Engineered Barrier System



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Engineered Barrier System

General Criteria

The Engineered Barrier System will support the key geologic repository mission by containing the waste, limiting radionuclide release to the natural barrier, controlling the external impacts on the engineered system, controlling impacts on the natural system, and providing waste package support and spacing. Collectively, the Engineered Barrier System will consist of the waste packages, waste package support hardware, and performance enhancing barriers. Alternative designs for the Engineered Barrier System are presented in the Design Options section of this document.

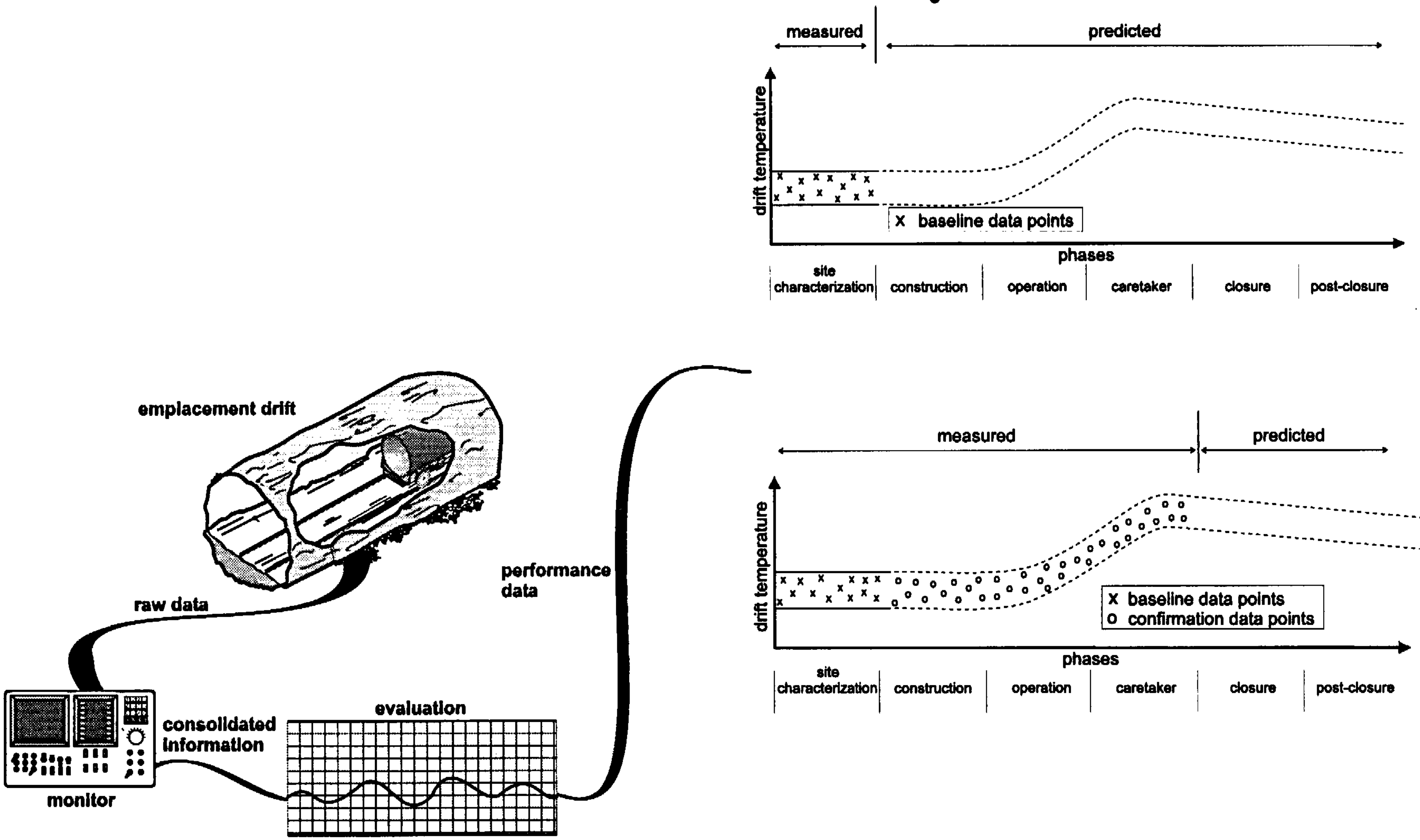
Design Description

The heat produced by the spent nuclear fuel in the waste packages will keep the rock around the drift dry for hundreds of years, which will reduce the corrosion rate of the waste packages. The components of the waste package are intended to contain the waste for thousands of years. The design characteristics of the waste packages were presented in the discussion on disposal containers.

The waste package support assembly will consist of a waste package pedestal and a waste package support. The pedestal and support will hold the waste package off the invert to prevent water from contacting the waste package if water is in the emplacement drift. The waste package support assembly is a modular design that allows flexibility in the waste package placement in the drifts and replacement of individual components in the event the support structure is damaged.

The invert will be made out of precast concrete. The main purpose of the invert is to provide a level drift floor and enable transport and support of the waste packages.

Performance Confirmation System



Performance confirmation involves gathering data on the waste packages, drifts, and mountain. The data will be evaluated and used to confirm the repository is performing as expected.

Performance Confirmation System

The performance confirmation system will provide data verifying that the subsurface conditions during construction, waste emplacement operations, and during the caretaker period are as expected. It also will verify that the natural and engineered systems and components are functioning as intended. The system will operate from the site characterization phase to the closure phase.

During the baseline period (the site characterization period), the performance confirmation system will develop information on the subsurface conditions and natural systems. The system also will monitor and analyze changes to the baseline information as a result of the site characterization and construction activities.

The goal of the confirmation period activities is to verify that actual subsurface conditions and changes resulting from the construction and operation of the repository are within limits.

The performance confirmation system will operate in the subsurface repository, as well as on the surface and in laboratories, acquiring and analyzing the data.

Design Description

To accomplish the performance confirmation activities, the following equipment and facilities will be required:

- five permanent observation or monitoring drifts with instrumented boreholes;
- an emplacement drift ventilation monitoring system;
- test alcoves in non-emplacement subsurface areas;
- a remotely operated gantry inspection system to monitor waste packages;
- a multi-purpose hot cell in the waste handling building with
    - 15 by 15 feet, 30 feet high,
    - 5-foot ordinary concrete stainless steel lined walls,
    - master-slave and electro-mechanical manipulators,
    - heavy duty dolly, and
    - 5-ton in-cell crane;
- a performance confirmation support area (about 10,000 square feet);
- a data acquisition system;
- surface-based monitoring and testing equipment; and
- laboratory testing equipment.

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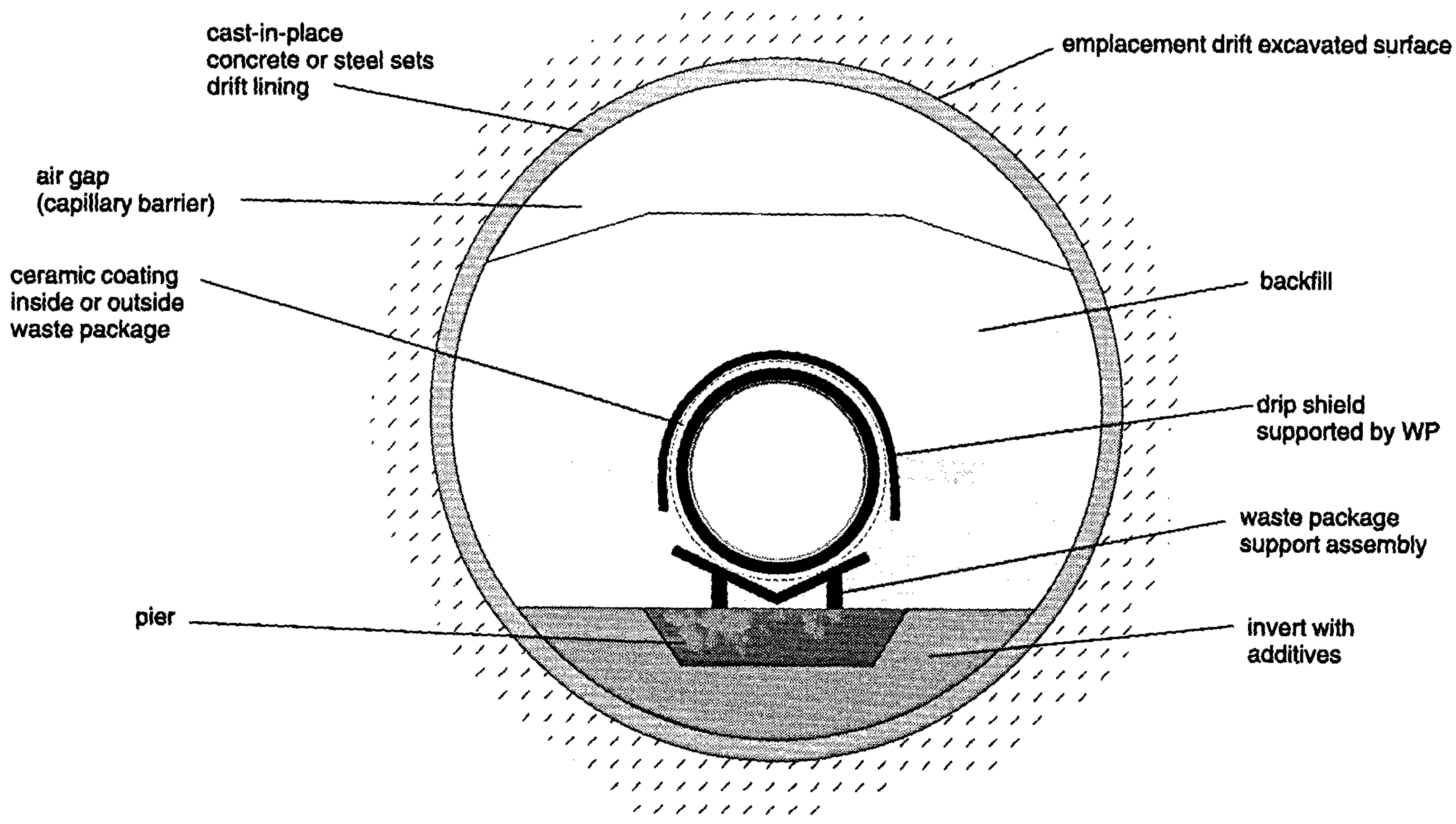
DESIGN OPTIONS

Engineered Barrier System Design Options



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Engineered Barrier System Design Options

In addition to the features of the Engineered Barrier System described previously, a number of design options are being evaluated to enhance the performance of the Engineered Barrier System. The design options include changes or additions to the drift lining, waste package, and invert.

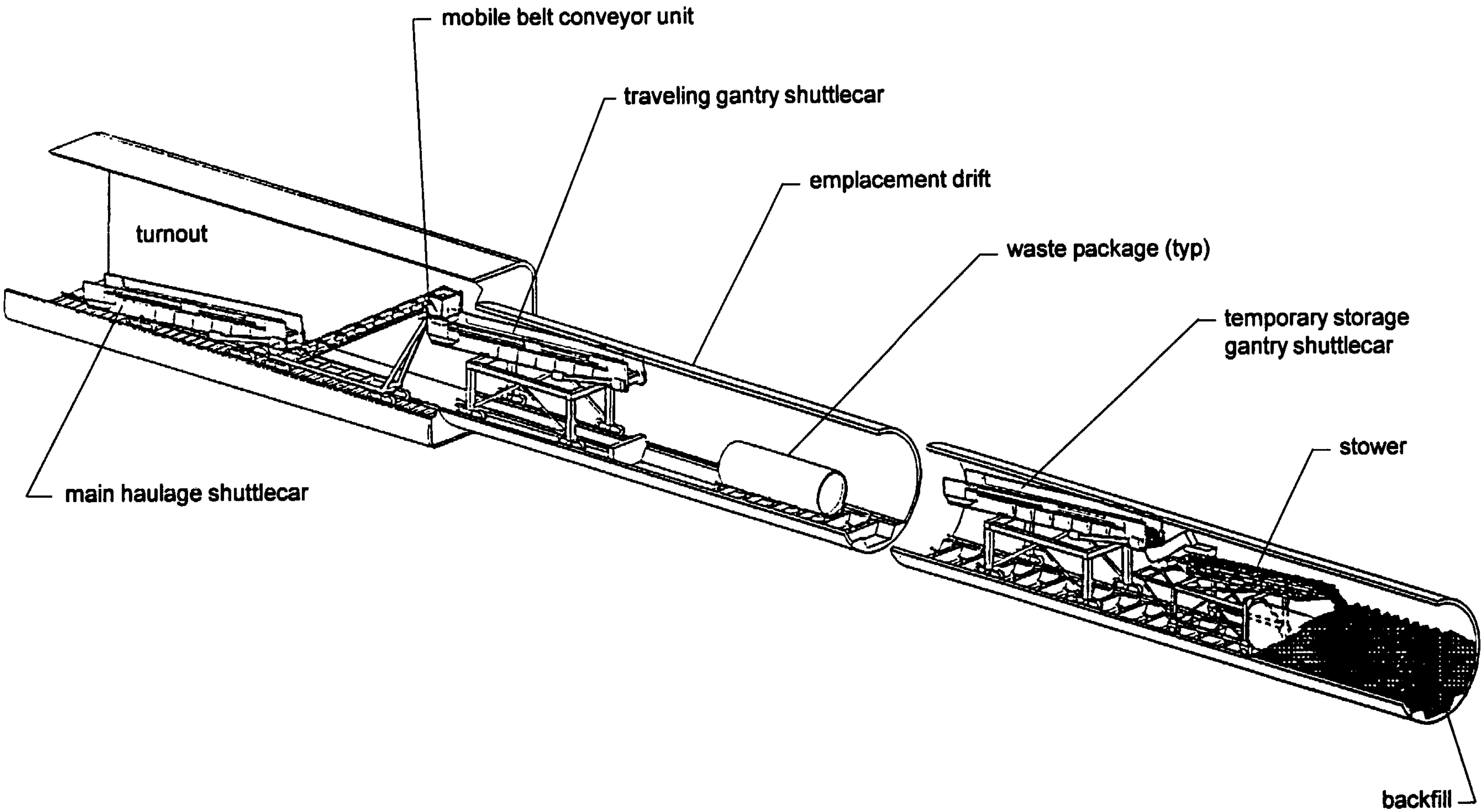
The waste packages in the reference design include a corrosion allowance barrier and a corrosion resistant barrier. The two barriers provide galvanic protection for the inner barrier and defense in depth by necessitating two different corrosion mechanisms for the respective barriers. In addition, a ceramic coating is being studied for placement either on the inside or outside of the waste package. The ceramic coating will be designed to minimize degradation of the waste package in wet environments.

Long-life drip shields may be used to divert any dripping water that may periodically enter the drifts around the waste package. The use of drip shields will be determined after evaluating their effectiveness for reducing corrosion rates and for reducing the annual radiological doses at the accessible environment

The reference design for the invert is precast concrete segments. However, additives that might be placed in the invert with characteristics to trap radionuclides are being examined..

The design selection process used to evaluate these options will be based on the scenarios predicted for the waste isolation period (temperatures, humidity, water flow, chemistry, and mechanical loads) as a function of time and location. The functions of the design options for the engineered barrier components then will be determined and evaluated with respect to their capability to delay breaching of the waste package; slow the release of radioactive materials from the waste package; and retard the release of radioactive materials from the Engineered Barrier System.

Backfill Emplacement System



Backfill Emplacement System

The Backfill Emplacement System will place backfill in the emplacement drifts (if required). This section presents the equipment and operations that may be used to emplace the backfill in the emplacement drifts (if required) to support waste isolation.

If backfill is to be placed in the emplacement drifts, it will be placed just prior to closure after the period of retrievability is over. The backfill to be emplaced is currently being studied and may consist of a dry granular material, possibly tuff excavated from the repository or quartz sand. This backfill material will be selected to ensure that corrosion of the waste packages is not enhanced and it will not lessen the waste isolation capabilities of the natural barrier.

The ventilation system will provide increased air flow in the fully loaded emplacement drifts to cool down the emplacement drifts. The cool down decreases the temperature in the emplacement drifts to allow the operation of the remotely operated backfill equipment. If the backfill is emplaced, it will not completely fill the emplacement drifts. The current concept would include placing the backfill in the emplacement drifts to ensure the waste packages are covered to a minimum depth of 0.6 meter. Backfill operations will be conducted remotely due to the high radiation field within the emplacement drifts.

Design Description

The Backfill Emplacement System will include the equipment required to prepare the backfill material at the surface of the repository, the equipment required to transport the backfill to the emplacement drift, and the remotely operated equipment required to emplace the backfill in the emplacement drifts.

An electrically powered locomotive will transport a main haulage shuttle car underground and back it into the turnout for the emplacement drift. Because the emplacement doors will be open when the haulage car is backed into place, the operation will be conducted remotely to prevent radiation exposure to workers.

Once the main haulage car has been backed into place, a mobile conveyor belt unit will transport the backfill to the traveling gantry shuttlecar. A chain conveyor in the bottom of the gantry shuttlecar will move the material from one end of the unit to the other. The traveling gantry shuttlecar then will travel over the waste packages and engage the temporary storage gantry shuttlecar. Once engaged, the backfill will be discharged to the temporary gantry shuttlecar and the traveling gantry shuttlecar then will return to the drift entrance to receive additional backfill.

The temporary storage gantry shuttlecar will use a conveyor belt to move the backfill to the stower. The stower will dump the backfill over the waste packages.