U.S. DEPARTMENT OF ENERGY YUCCA MOUNTAIN DESIGN UPDATE

P. G. Harrington
DOE Office of Repository Development
1551 Hillshire Drive, Las Vegas, NV 89134-6321

ABSTRACT

This paper provides a summary of the design activities that have taken place during 2003 on the Yucca Mountain Project (YMP). In addition to a series of internal studies conducted on all phases of repository design, international experience was sought and incorporated into enhancements to the surface facilities. This has resulted in significant improvements to the surface facility building layouts and functions. Improvements have also been made to the subsurface facility design and engineered barrier designs.

INTRODUCTION

Over the last year, the number of facilities, the facility layout, and the designs of several YMP facilities have evolved. These changes were implemented to improve facility operations, reduce facility size, cost and construction duration, and to reduce project risk. The design and operating mode of the repository have evolved as more was learned about the site and about the performance contribution of design attributes and operational objectives.

REPOSITORY DESIGN DEVELOPMENT

Spent nuclear fuel (SNF) and vitrified high-level radioactive waste (HLW) will be transported to the repository in NRC-certified transportation casks, using U.S. Department of Transportation licensed cask transportation contractors.

Upon arrival, the casks will be inspected at the Cask Receipt Security Station and parked in the rail car or truck staging areas prior to being scheduled into the Transportation Cask Receipt Building (TCRB).

Upon arrival at the repository, the transportation cask railcar, legal weight truck, or overweight truck cask trailer will be received at the Cask Receipt Security Station where an access security check will be performed. Security officers will conduct a visual survey of the vehicle, trailer or railcar, and cask. A visual inspection of the complete transport system will be performed and the results noted in the shipment manifest file (e.g., presence of tamper indicating devices, overall status of shipment, etc.). The cask will then be cleared for entry into the geologic repository operations area.

From the Cask Receipt Security Station, the shipment will be towed to the railcar or truck staging areas. Monitored Geologic Repository (MGR) personnel will verify the shipping manifests, then inspect and survey each SNF/HLW cask and its trailer or railcar. Rail shipments will be queued in a rail car staging area, and truck shipments will be queued in a truck staging area. When the cask is scheduled for processing, it will be moved to a waste handling facility.

The waste handling facilities, consisting of the TCRB, Canister Handling Facility, combined Dry Transfer Facility 1/Remediation Building, and Dry Transfer Facility 2, will receive, prepare, and package the waste for emplacement underground in the repository or placement on an aging pad. Canistered waste would be handled mainly in the Canister Handling Facility and the Shielded Canister Facility, while bare fuel would be handled in the Dry Transfer Facilities. Waste handling operations will be conducted using remotely operated equipment. Thick reinforced concrete walls and controlled area access techniques will be used to protect workers from radiation exposure. The waste handling structures and equipment will be designed to withstand the effects of ground motion from earthquakes and other natural events.

Waste packages will be moved from the surface to the emplacement drifts using a rail-mounted waste package transporter. Once the shielded waste package transporter arrives at the assigned emplacement drift and the drift isolation doors are opened, the waste package transporter doors will be opened and the waste package will be moved out of the transporter. An in-drift gantry will lift the waste packages by their supporting pallets and deposit them in their designated position inside the drift. Before the repository is permanently closed, drip shields will be placed over the waste packages to divert any water that might drip from the top of the emplacement drifts, and to act as a rockfall shield.

Emplacement operations will take place in finished emplacement drifts at the same time as future emplacement drifts are being constructed. During construction, physical barriers and separate ventilation systems will be provided between the development side (i.e., panels under construction) and the waste operations side (i.e., panels where waste is being emplaced) to minimize the risk of worker exposure to radiation from the waste.

SURFACE FACILITIES

The repository surface facilities will be located in the Geologic Repository Operations Area (GROA), the South Portal development area, the North Construction Portal development area, the Balance-of-Plant area, and the surface shaft areas. Together, these areas will cover about 1,500 acres of land, where about 35 structures will be built to house the systems, structures, and components needed for safe and effective repository operations.

All waste handling operations will be carried out in the GROA. This area comprises the facilities necessary to receive, package, and emplace waste in the repository. Waste transfer operations will occur in two Dry Transfer Facilities and a Canister Handling Facility. In these facilities, waste will be transferred from a transportation cask to a waste package or an aging cask. To protect workers and the public from exposure to potentially harmful radiation, these facilities will include thick reinforced concrete walls designed to withstand potential handling mishaps and earthquakes and other natural phenomena. Within the TCRB, the transportation casks will be inspected, prepared for movement into the waste transfer facilities, and empty casks prepared for shipment offsite. The construction of these facilities will be phased to correspond to the planned waste receipt rates and to allow initial waste receipt in 2010.

The recent changes to the surface facilities include:

- Modifying the layout of the Transportation Cask Receipt Building
- Modifying the layout of the Waste Package Receipt Building
- Modifying the configuration and size of the Dry Transfer Facilities
- Combining the Remediation Building with Dry Transfer Facility 1
- Adding a Canister Handling Facility
- Increasing the capacity of the Aging Facility up to 40,000 metric tons of heavy metal (MTHM)
- Eliminating the Low-Level Waste (LLW) Building.

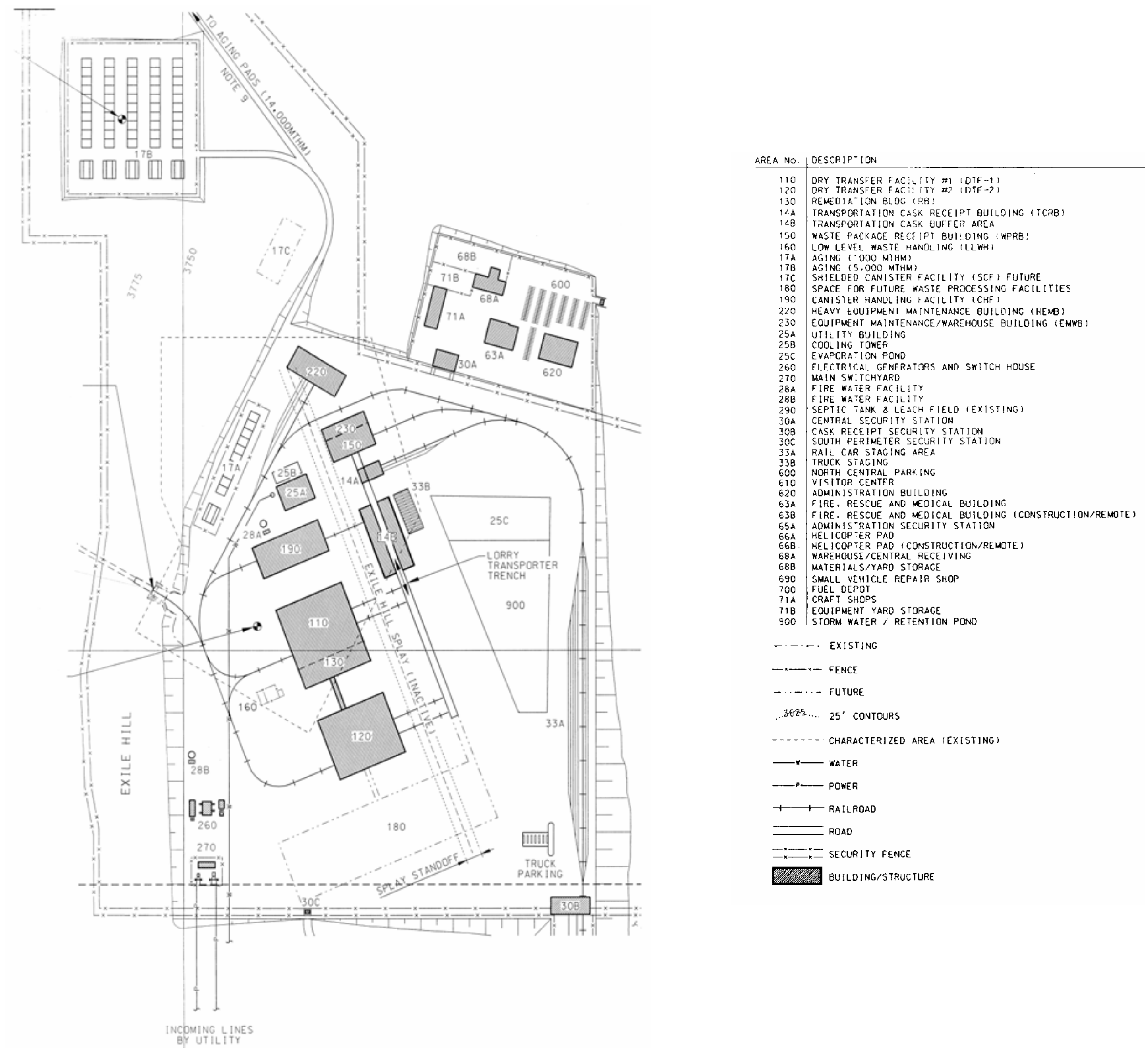

Fig. 1 Surface Facilities Layout at North Portal

Dry Transfer Facility 1

Dry Transfer Facility 1 is located in the GROA near the North Portal. Dry Transfer Facility 1 will handle all transportation cask, site-specific aging cask, and waste package configurations. The facility will receive, handle, and process commercial SNF, DOE SNF, Naval SNF, and DOE HLW forms received in a variety of truck or rail transportation casks.

The physical layout will include areas for waste package receipt, loading, closure, and subsurface transporter loading. The layout will also provide staging areas for casks, SNF assemblies, SNF canisters, HLW canisters, and waste packages.

Waste transfer areas will include operating galleries that are separated from the transfer cells by thick concrete and steel reinforced walls. Shield walls, windows, and doors will protect personnel, who remotely operate the waste transfer systems. These areas will also be independently ventilated and air conditioned so operators can safely and remotely control operations without entering high radiation zones or contaminated areas.

Dry Transfer Facility 1 will have a limited-capacity, in-process waste staging area. This will consist of approximately 3 transportation casks, 3 waste packages, 48 pressurized water reactor SNF assemblies, 72 boiling water reactor SNF assemblies, and 10 DOE SNF or HLW canisters.

Remediation Building

This building will consist of a multilevel, monolithic reinforced concrete structure that will house a below-grade fuel pool. The pools will be reinforced concrete walls with a stainless steel liner to prevent loss of water. The stainless steel liner plates will serve as the primary containment boundary. The pools will be equipped with a leak detection system.

Design features for the pool will include fuel staging racks and a separation wall to protect the staged fuel from a tipping cask in the cask unloading area of the pool. Fuel staging racks within the pool will be designed to stage a minimum of one cask of unloaded fuel. The pool will also use a weir system and expansion tank for water recovery and return of the water displaced by the casks being placed in the pool.

The concrete walls will serve as the secondary containment. The foundation system will be a rigid, reinforced concrete mat. In addition to the facilities required for waste processing functions, space will be provided for hot (radiological) facilities, as well as cold (non-radiological) support facilities.

Dry Transfer Facility 2

The function and design of Dry Transfer Facility 2 will be similar to Dry Transfer Facility 1. Dry Transfer Facility 2 will be located in the GROA near the North Portal, south of Dry Transfer Facility 1.

Canister Handling Facility

The Canister Handling Facility will house structures, systems, and components necessary to handle, transfer, and package canisterized SNF and HLW.

The Canister Handling Facility will be located in the GROA near the North Portal, immediately north of Dry Transfer Facility 1. The Canister Handling Facility will be a limited throughput capacity facility that can provide the capability to receive sealed canister shipments (e.g., Naval SNF and DOE SNF/HLW). The Canister Handling Facility design will allow for receipt of transportation casks and canisters by site-specific rail transfer cart, legal weight truck, and overweight truck.

The design will provide capability for transfer of DOE canisters within the facility to waste packages or to site-specific aging casks. The facility will also be used to receive site-specific aging casks, unload the canisters, and load waste packages for emplacement. The Canister Handling Facility will have a limited capacity for in-process waste staging. This will consist of shielded staging inside the Canister Handling Facility for 10 DOE SNF/HLW canisters.

Surface Aging Facility

The Surface Aging Facility will house structures, systems, and components necessary to age waste in licensed storage containers, cooling that waste prior to emplacement as necessary to meet the repository thermal requirements. The aging facility design will be phased so that at least a portion will be operational in 2010. The design and construction of the aging facility will be similar to facilities currently in use at nuclear power plants. The aging pads will be located in close proximity to the dry transfer facilities to ensure reasonable transportation distance and time to place a site-specific cask into aging.

The aging facility adjacent to the North portal will be limited in size to approximately 1,000 MTHM of waste or 100 site-specific casks. The layout can be expanded in additional increments of nominally 5,000 MTHM of waste, or approximately 500 site-specific casks. Provisions are being established in the site layout to include an additional 14,000 MTHM of aging capacity north of the GROA, while not precluding the ability to expand to a total of 40,000 MTHM for the entire site.

The reinforced concrete aging pads will be sized considering current commercial vendor designs for five different dry storage cask systems. Since the size of the aging area and its layout depend on the storage system selected, the storage system with the greatest demand for site space will be used to establish the aging pad space requirements. The aging facility will be designed for natural and human-induced events, as required, including seismic events and tornado wind loads and missiles, as required.

Transportation Cask Receipt Building

The TCRB will be located in the GROA adjacent to the Transportation Cask Buffer Area. The primary functions of the TCRB will be to receive loaded transportation casks, remove personnel barriers, and place the cask on a site-specific rail transfer cart for movement to a waste transfer facility.

Only legal weight trucks and rail carriers will be received directly into the TCRB. Shipments from heavy haul trucks will be transferred to the rail system prior to movement to the TCRB.

The material handling system in the TCRB will provide the capability to receive and inspect transportation casks from the carrier, then prepare the casks for unloading in a waste transfer facility. Six parallel tracks and roadways (three for rail carriers and three for truck carriers) will permit the simultaneous handling of rail and truck carriers.

Waste Package Receipt Building

The Waste Package Receipt Building has recently been consolidated with the TCRB. The waste package receipt portion of the building will receive empty waste packages from an off-site fabricator. It will contain space and equipment to receive, inspect, clean, and stage empty waste packages and waste package lids, add lifting collars to the empty waste packages, and load empty waste packages and lids onto site-specific rail transfer carts.

Transportation Cask Buffer Area

The Transportation Cask Buffer Area will be in the GROA adjacent to the Transportation Cask Receipt and Waste Package Receipt Building. It will consist of a series of parking areas for the rail-based site-specific rail transfer carts, which provides staging for transportation casks prior to their movement to a waste transfer facility.

Low-Level Waste Building

The current design has eliminated the LLW Building. LLW handling will be provided through a separate contract and will require a small processing area. This area is selected to provide a central location within the GROA for LLW processing, staging, and preparation for offsite transportation to an ultimate disposal facility. The LLW handling area will be located near the Canister Handling Facility and Dry Transfer Facilities where LLW will be generated.

SUBSURFACE FACILITIES

The primary functions of the subsurface facilities are to transport waste packages from the surface to the subsurface, emplace waste packages, monitor operations and repository performance, retain the capability to retrieve waste, and decommission and close the repository. Waste retrieval capability must be maintained throughout the repository preclosure period, which is a minimum of 50 years after emplacement begins. The subsurface facilities will provide storage capacity for 70,000 MTHM of SNF and HLW.

The layout of the subsurface facilities has changed to facilitate rail transport of the waste package to the emplacement drifts. The ground control in the emplacement drifts has changed from carbon steel steelsets or mesh with grouted carbon steel rock bolts to a stainless steel liner with stainless steel friction type rock bolts.

The underground facilities will consist of drifts, or tunnels, where the waste will be emplaced; ramps and shafts for access and ventilation; and drifts for installation of equipment to monitor the performance of the repository. The North Portal, adjacent to the above ground operations area, will provide access to the active emplacement drifts. The South Portal and the North Construction Portal will provide access for construction of new drifts.

Waste packages will be emplaced in dedicated drifts, supported on emplacement pallets, and aligned end-to-end on the drift floor. The repository emplacement drifts will be built in a series of panels, each comprising a set of emplacement drifts, and phased to match the planned throughput of the surface facilities. The total subsurface emplacement area required to accommodate 70,000 MTHM (the current statutory limit) is about 1,000 acres, with waste packages spaced 0.1 meter end to end. This includes approximately 210,000 feet (40 miles) of excavated emplacement drifts in four panels. About 11,000 waste packages and their pallets will be placed in these drifts. Panel 1 includes a single performance confirmation drift and eight emplacement drifts excavated to an 18-foot diameter at a center-to-center drift spacing of 266 feet. A portion of Panel 1 will be operational at initial operations.

Construction of additional emplacement drifts will take place concurrently with emplacement operations in completed emplacement drifts. During construction, physical barriers and separate ventilation systems will be provided between the development side (i.e., drifts under construction) and the waste operations side (i.e., drifts where waste is being emplaced) to minimize the risk of worker exposure to radiation from the waste.

Recent major changes to the subsurface facilities include:

- Eliminating the fifth emplacement panel.
- Returning to a rail-based waste package emplacement system, from the multi-wheeled technology previously considered.
- Increasing the turnout radius and orientation of the emplacement drift starter tunnels to accommodate rail transport of the waste package.
- Moving the ventilation control doors to the outer end of the emplacement drift turnouts.
- Changing the ground control system in the emplacement drifts to a continuous lining of thin perforated stainless steel with stainless steel friction type rock bolts.

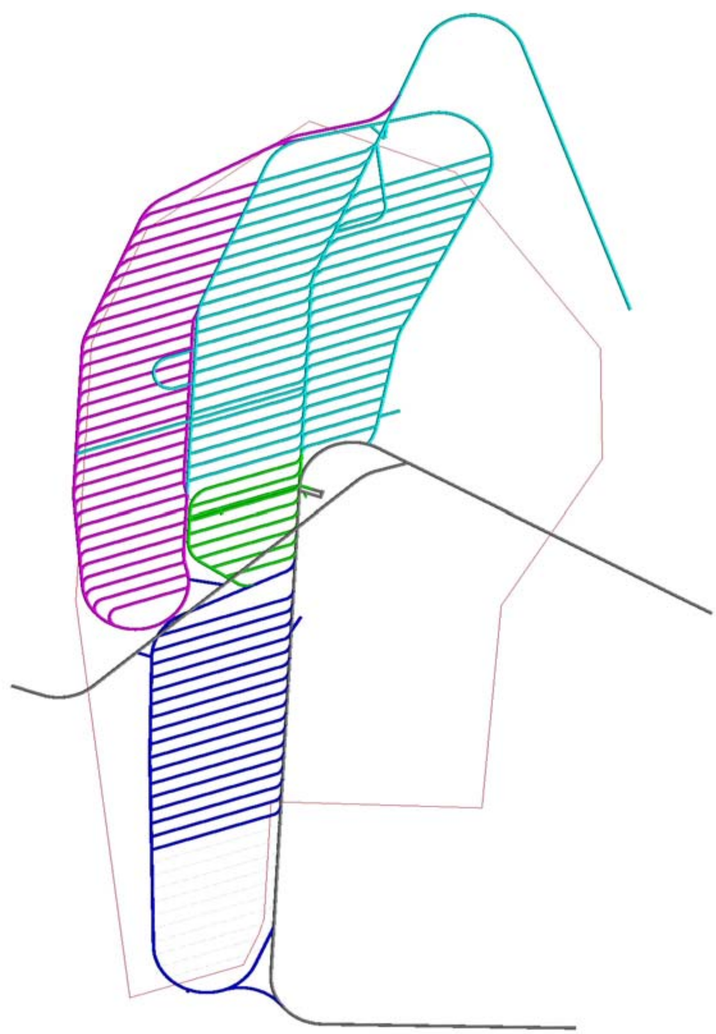

Fig. 2 Layout of the Subsurface Drifts

The scope of subsurface facility operations begins with transporting the loaded waste package on a pallet from the surface facilities to the emplacement drift. The waste package transporter will carry a single waste package and pallet from Dry Transfer Facility 1, Dry Transfer Facility 2, or the Canister Handling Facility to the North Portal, down the North Ramp, and to the selected emplacement drift turnout. At the emplacement drift, the emplacement drift doors will be opened, the waste package transporter docked and the waste package and pallet pushed onto the transfer deck.

The waste package emplacement gantry will move from inside the emplacement drift over the waste package and pallet, straddling the transfer deck area. The gantry will lift the waste package by gripping the sides of the pallet, move the waste package into the drift to the emplacement location, and lower the waste package and pallet down to the drift invert. The waste package transporter will return to the surface facilities for another transportation cycle.

Other systems and facilities that will directly support subsurface operations and construction activities include repository ventilation equipment at the exhaust shaft openings, construction staging areas adjacent to the North Construction Portal and South Portal, and muck conveyance and storage facilities.

Waste Package Transporter

The waste package transporter will be based on existing rail technology to transport heavy loads, such as waste packages and associated shielding, to the emplacement drifts. A recent design change to the waste package transporter is to return to a rail-based system in lieu of the omnidirectional, multi-wheeled method previously considered.

The waste package transporter bedplate will consist of a thick steel plate that distributes the waste package and pallet load through rollers (attached to the bottom of the bedplate) to the transporter. The roller assembly will run on an inverted channel installed on the deck of the transporter. The channel will guide the bedplate rollers to a position centered with the emplacement gantry for pickup.

The bedplate will be attached to the ends of two gear-driven semi-rigid chains that run in floor-mounted guides on each side of, and parallel to, the bedplate as it rests on the transporter. The chain guides will extend from inside the shielded enclosure to the emplacement drift dock. The semi-rigid chain attached to the bedplate will push the bedplate onto the dock and draw it back into the shielded transporter enclosure. The bedplate will incorporate restraints and spacers to immobilize the waste package, pallet, and bedplate inside the transporter for safe transit to the emplacement drift.

The shielded enclosure will be designed to meet the radiation dose rate limit of 100 millirem per hour on the transporter surface. This will be accomplished with a thick carbon steel enclosure wall. The steel wall will provide sufficient shielding for inaccessible areas (i.e., the deck floor below the shielded enclosure) during normal operations. In addition to the carbon steel, the shielded enclosure will have a borated polyethylene layer for neutron shielding.

ENGINEERED BARRIER SYSTEM

The components of the engineered barrier system are designed to complement the natural barriers in isolating waste from the environment. The engineered barrier system design includes the waste package, support pallets, drip shield, and emplacement drift invert, and the only significant change over the last year is with respect to the closure lid details.

Waste packages will have a dual-metal design using two concentric cylinders. The inner cylinder will be made of Stainless Steel Type 316. The outer cylinder will be made of a corrosion-resistant, nickel-based metal, Alloy 22 (UNS N06022). Alloy 22 will protect the stainless steel inner cylinder from corrosion, and the stainless steel Type 316 will provide structural support for the thinner Alloy 22 cylinder. Each waste package will have a pallet for structural support. The pallet will be fabricated from Alloy 22 and stainless steel Type 316.

The invert will include engineered structures and materials at the bottom of the emplacement drifts that support the pallet and waste package, drift rail system, and drip shield. It will be composed of two parts, the carbon steel invert structure and the crushed tuff ballast.

Drip shields will be installed at the end of the operational period. The drip shields will divert moisture that might drip from the drift walls around the waste packages to the drift floor. The drip shields will also protect the waste packages from rockfall.

Recent changes to the Engineered Barrier System included changing the closure lid design to simplify the waste package closure process, and to reduce or eliminate the need for post-weld stress mitigation. The inner stainless steel lid was made thinner, and its closure mechanism was changed from a full penetration weld to a shear ring with seal welds. The middle Alloy 22 lid was changed from a full penetration weld to a fillet weld, which eliminated the need for stress mitigation. The outer Alloy 22 lid was changed from an extended configuration to a flat lid. This remains a full penetration weld, but the revised configuration allows substitution of laser peening or low-plasticity burnishing in lieu of induction annealing as the stress mitigation technique.

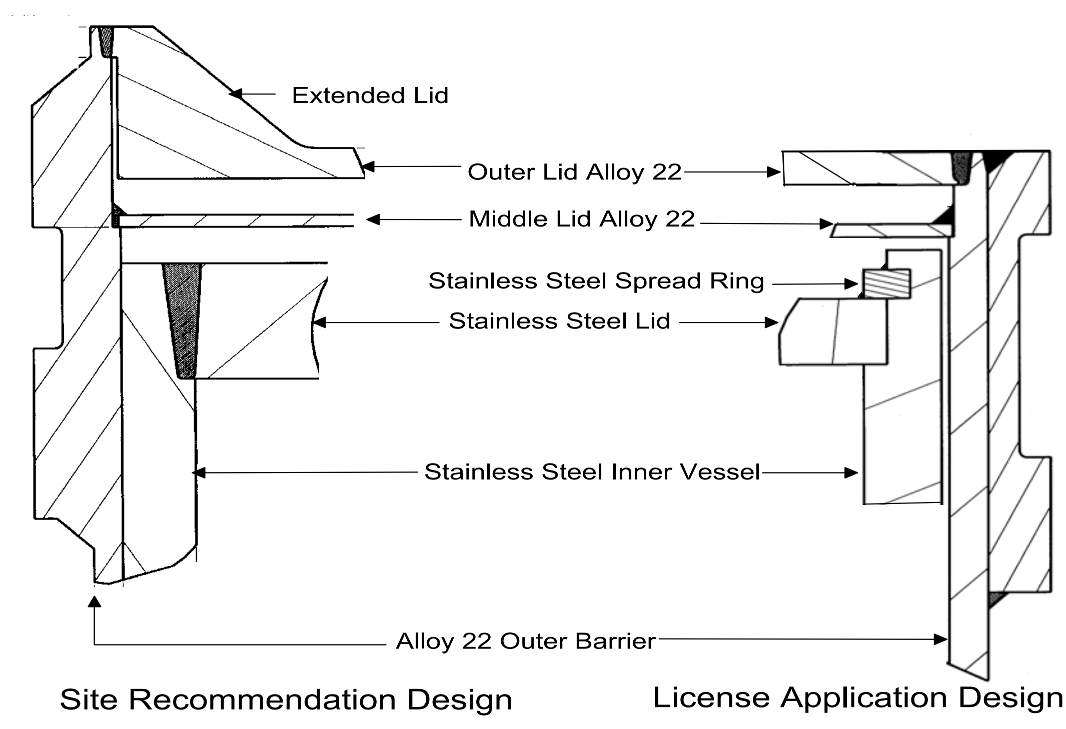

Fig. 3 Waste Package Closure Changes

PATH FORWARD.

The proposed Yucca Mountain repository design satisfies the requirement to accommodate the range and quantities of waste forms planned for disposal. The phased approach to construction has been determined to be viable, provides opportunities to optimize future facility designs based upon lessons learned, and allows repository operations to begin within the current project schedule. Uncertainties in the design have been identified and are being addressed to ensure that the design presented to the NRC in the license application meets regulatory requirements. DOE will continue to evaluate the repository design to ensure compliance with regulatory requirements and to optimize construction and operations.