TECHNICAL SUPPORT FOR GEIS:
RADIOACTIVE WASTE ISOLATION
IN GEOLOGIC FORMATIONS

MASTER

Volume 8

Repository Preconceptual Design Studies: Salt

April 1978

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UNION
CARBIDE

OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

prepared for the U.S. DEPARTMENT OF ENERGY under
U.S. GOVERNMENT Contract W-7405 eng 26

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Volume No.	Volume Title	Prepared by*
TM-36/1	Executive Summary	SAI
TM-36/2	Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies	SAI
TM-36/3	Stratigraphies of Salt, Granite, Shale, and Basalt	D&M
TM-36/4	Baseline Rock Properties-Salt	D&M
TM-36/5	Baseline Rock Properties-Granite	D&M
TM-36/6	Baseline Rock Properties-Shale	D&M
TM-36/7	Baseline Rock Properties-Basalt	D&M
TM-36/8	Repository Preconceptual Design Studies: Salt	PBQD
TM-36/9	Drawings for Repository Preconceptual Design Studies: Salt	PBQD
TM-36/10	Repository Preconceptual Design Studies: Granite	PBQD
TM-36/11	Drawings for Repository Preconceptual Design Studies: Granite	PBQD
TM-36/12	Repository Preconceptual Design Studies: Shale	PBQD
TM-36/13	Drawings for Repository Preconceptual Design Studies: Shale	PBQD
TM-36/14	Repository Preconceptual Design Studies: Basalt	PBQD
TM-36/15	Drawings for Repository Preconceptual Design Studies: Basalt	PBQD
TM-36/16	Repository Preconceptual Design Studies: BPNL Waste Forms in Salt	PBQD
TM-36/17	Drawings for Repository Preconceptual Design Studies: BPNL Waste Forms in Salt	PBQD
TM-36/18	Facility Construction Feasibility and Costs by Rock Type	PBQD
TM-36/19	Thermal Analyses	SAI
TM-36/20	Thermomechanical Stress Analysis and Development of Thermal Loading Guidelines	D&M
TM-36/21	Ground Water Movement and Nuclide Transport	D&M
TM-36/22	Nuclear Considerations for Repository Design	SAI
TM-36/23	Environmental Effluent Analyses	SAI

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ABSTRACT

This volume, Volume 8 "Repository Preconceptual Design Studies: Salt," is one of a 23-volume series, "Technical Support for GEIS: Radioactive Waste Isolation in Geologic Formations," Y/OWI/TM-36, which supplements the "Contribution to Draft Generic Environmental Impact Statement on Commercial Waste Management: Radioactive Waste Isolation in Geologic Formations," Y/OWI/TM-44. The series provides a more complete technical basis for the preconceptual designs, resource requirements, and environmental source terms associated with isolating commercial LWR wastes in underground repositories in salt, granite, shale and basalt. Wastes are considered from three fuel cycles: uranium and plutonium recycling, no recycling of spent fuel and uranium-only recycling.

This document describes a preconceptual design for a nuclear waste storage facility in salt. The facility design consists of several chambers excavated deep within a geologic formation together with access shafts and supportive surface structures. The facility design provides for: receiving and unloading waste containers; lowering them down shafts to the mine level; transporting them to the proper storage area, and emplacing them in mined storage rooms. Drawings of the facility design are contained in TM-36/9, "Drawings for Repository Preconceptual Design Studies: Salt."

PREFACE

Project Background

One of the major problems related to the production of electricity by light-water nuclear reactors is the management of radioactive wastes generated by the use of nuclear fuel. However, the subject is considered amenable to a rational solution, and the technology involved is considered to be well within the capabilities of our present-day technological base.

An important step toward the realization of an effective waste management program is the preparation of the generic environmental impact statement for commercial waste management. A pivotal issue in waste management is the means of providing long-term, permanent storage of these wastes in a manner that best assures their isolation from the biosphere. Analyses spanning two decades have generated the widely supported concept for providing final isolation of these nuclear wastes in deep geologic formations. Therefore, the Office of Waste Isolation* was assigned the responsibility for preparation of the sections of this generic statement that deal with deep geologic waste isolation.

The original concept for deep geologic disposal was first advanced in 1957 when a National Research Council Advisory Committee of the National Academy of Sciences suggested the burial of solid radioactive wastes in salt deposits. To date, the majority of the research, development, and demonstration (RD&D) activities have been in salt. The current United States Department of Energy (DOE) National Waste Terminal Storage (NWTs) program calls for the selection of two sites overlying suitable salt formations by 1979, followed by the construction and start-up in 1985 of one

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*Operated by Union Carbide Corporation Nuclear Division for the Department of Energy.

NRC-licensed repository designed for the permanent disposal/isolation of commercial nuclear wastes in a salt formation at one of these two sites. In addition to this activity in salt, vigorous RD&D programs have been initiated to determine the appropriateness of various hard rocks as host media for a repository.

The deep geologic isolation portion of the generic statement considers repositories located in salt, granite, shale, and basalt. The repositories are designed to handle wastes from the nuclear fuel cycle in which the spent fuel is considered a waste (no re-processing) or from either of two fuel cycles that include re-processing--the cycle with uranium and plutonium recycle and that with only uranium recycle. To prepare this contribution, the Office of Waste Isolation contracted with Dames & Moore, Parsons Brinckerhoff Quade & Douglas, Inc. and Science Applications, Inc. In order to prepare this description, generic sites were defined, preconceptual repository designs completed, and resource requirements and effluents from the repositories identified. The preconceptual repository designs for the salt host formation were based on more than two decades of analysis and in-situ experimentation. The data base upon which the repository designs for the non-salt host formations were based is much more sparse since repository-oriented analyses of these formations have been proceeding only for the last couple of years. For each of the host rocks additional analyses were performed during the conduct of these studies. Details of this additional technical work are described within the twenty-three volumes of this report.

For an overview of these preconceptual repository design studies, the study objectives and scope, and the major study assumptions, the reader is referred to Volume 1 of this series, the Executive Summary (Y/OWI/TM-36/1).

Volume Summary

This volume, "Repository Preconceptual Design Studies: Salt," describes the scope of the generic repository and various design

assumptions (Section 1.0). Sections 2.0 and 3.0 outline the surface facilities and utilities of the repository. Mine-operating and waste receiving shafts are treated in Section 4.0 and mining and waste placement operations are discussed in Section 5.0. Section 6.0 examines the ventilation systems for the facilities of the repository.

1.0 INTRODUCTION

1.1 Scope of the Generic Repository

Preconceptual design studies have been prepared for an underground nuclear repository in salt that stores nuclear wastes generated from commercial power plants. The overall design of the repository may be divided, for purposes of analysis, into three major components: (1) surface facilities; (2) shafts; and (3) underground storage rooms.

1.1.1 Surface Facilities

The surface facilities, which occupy approximately 200 acres of land, are designed to serve all functions associated with handling the waste on the surface. These functions include:

- o receipt and unloading of wastes in specially designed containers from rail cars
- o transfer of waste containers to inspection stations
- o decontamination of waste containers, if required
- o overpacking when needed
- o preparation of waste for descent to the storage level.

The repository design includes two basic waste handling streams: one for wastes that require shielding and hot-cell facilities (canistered waste), and one for wastes that do not (low-level waste). In addition to the surface facilities required for processing the wastes, additional support installations, such as an administration building, clinic, cafeteria, utility systems, and radwaste management facilities are provided. An artist's conception of a typical federal repository is shown in Figs. 1 and 2.

1.1.2 Shafts

Five shafts have been provided for the repository. These are:

- o Canistered Waste Shaft--for transporting canisters of waste to the storage level

- o Low-Level Waste Shaft--for transporting pallets containing drums of low-level waste to the storage level
- o Men and Material Shaft--for transporting personnel and equipment to and from the storage level as well as transporting excavated material to the surface
- o Ventilation Supply Shaft--for supplying fresh air for personnel and equipment requirements
- o Ventilation Exhaust Shaft--for removing exhaust air from mining, backfilling, and waste placing operations.

1.1.3 Underground Storage Rooms

Once the waste has been lowered down the shaft it would be transported to the storage rooms. Initially, the repository is assumed to operate in a retrievable mode for a short period of time to validate repository operations and safety. During this period when the retrievability option is maintained, all waste can be removed from the repository at about the same rate and with about the same effort as storage placement, should this be desired. After the repository has satisfactorily operated for a certain period of time (currently assumed to be five years), operations performed to maintain retrievability would be terminated and the storage rooms would be backfilled. Mining, placement and backfilling can continue without this retrievability feature. Once all the storage rooms are backfilled, the surface facilities would be decommissioned and dismantled, and all shafts would be plugged and sealed. The possibility of a 25 year retrievability is discussed in paragraph 5.11.

1.2 Alternative Fuel Cycles

Three alternative fuel cycles for light water reactors (LWRs) have been identified for analysis.¹ Because of the different thermal loadings associated with each fuel cycle, capacities for the repository design vary according to each cycle. The cycles are:

Cycle I: Total Recycle -- Spent fuel is reprocessed to extract and recover uranium (U) and plutonium (Pu). The reprocessed waste consists of: (1) high-level waste (HLW) con-

taining fission products, actinides and other radioactive isotopes; (2) cladding waste (CW) and other intermediate-level transuranic (IL-TRU) waste; and (3) low-level transuranic (LL-TRU) waste. The high-level waste is assumed to arrive at the repository ten years after the fuel assemblies from which the HLW was generated were discharged from reactors. All other wastes from this fuel cycle are assumed to arrive at the repository five years after discharge from the reactor.

Cycle II: Spent Unreprocessed Fuel (SURF) Cycle -- Spent fuel assemblies are not reprocessed but are directly disposed of as waste. In this alternative, the repository will receive intact spent LWR fuel assemblies and low-level waste. For the purposes of this study, it is assumed that Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) spent fuel assemblies are aged a minimum of ten years after removal from the reactor, prior to delivery to the repository and low-level wastes are one year old when they arrive at the repository.

Cycle III: U Only Recycle (with Pu in HLW) -- Spent fuel is reprocessed but only the uranium is removed from the waste. In partial reprocessing operations, the uranium is recovered for reactor recycle and the plutonium is discarded in solid form with the HLW. In addition, the repository will receive cladding waste, intermediate-level transuranic waste, and low-level transuranic waste, as in Cycle I. Similarly, the HLW is assumed to be ten years old and all other wastes are assumed to be five years old upon arrival at the repository.

1.3 Canister Design Assumptions

For purposes of the design of a reference repository, certain assumptions have been made concerning the form in which the wastes will be received at the repository? The assumed waste containers are summarized in Table 1-1. All high-level wastes from Cycles

I and III, both PWR and BWR spent fuel assemblies from Cycle II, and intermediate-level transuranic waste and cladding wastes from Cycles I and III are anticipated to arrive at the repository in sealed steel canisters. Depending upon waste type, the outside diameter of these canisters may range from 8-5/8 in. to 14 in. and the overall length may range from 10 ft. to 16 ft. Although the specific dimensions of the canisters vary by waste type, all canisters, regardless of fuel cycle, are handled remotely and require shielding for radiation attenuation.

Physical similarities among the canisters for high-level, intermediate-level, cladding and spent fuel wastes, enabled a single receiving facility and common handling procedures to be developed for all canistered wastes, scaled as appropriate for the respective fuel cycles.

All low-level wastes will be received at the repository in 55 gal. drums and will be handled without shielding in a receiving building separate from the canistered waste.

1.4 Geotechnical Factors That Influence Design³

Because of geological characteristics and the general stratigraphic setting of an in-situ salt, many of the design and layout features of the surface and subsurface facilities as well as the amount of waste that can be stored will be influenced. These geotechnical characteristics include:

- o effects of heat on rock strength
- o rock movement
- o rock stability and closure
- o groundwater movement.

1.4.1 Effects of Heat on Rock Strength

At high temperatures the strength of rock is diminished as the rock structure begins to break down. In salt, decrepitation begins to occur in the range between 250°C and 400°C. To prevent weakening of the rock adjacent to the waste packages and the concomitant problems it would pose to retrievability, the thermal

loading should be adjusted so that temperatures do not exceed critical values in the large volumes of rock immediately adjacent to the canisters.

To maintain room safety and to reduce the possibility of progressive spalling failures, the temperature of the rock surfaces in the room walls and roof should also be held below the values that cause excessive strength loss.

1.4.2 Rock Movement

The mined excavation and thermal loading from the waste materials would create stresses which would cause the rock surrounding and overlying the repository to react or move. Mining activities would cause the surrounding rock to subside or move into and towards the mined opening. In contrast, the thermal loading would expand the rock and cause heaving to occur.

The repository layout and geometry and the allowable thermal loading should be designed to minimize rock movements so that the safety or integrity of the shafts is not adversely affected. Movements at the ground surface should be less than that which would cause distress in any structure. In addition, rock movement should not cause disruption or shearing of any aquifers in the vicinity of the repository.

1.4.3 Rock Stability and Closure

Salt is a relatively pliable material with low to moderate strength and pronounced creep behavior, particularly at high temperatures. It undergoes large amounts of deformations without rupturing. Because of these properties, additional considerations must be given to establishing the mine layout, room geometry, and allowable thermal loadings in a repository in salt. Not only must the overall stability of the room and pillars be maintained, but the room closure during the operational phase of the facilities must be limited to acceptable amounts.

1.4.3.1 Room and Pillar Stability

For the generic repository in bedded salt, the room and pillar stability was evaluated using information from experimental and analytical studies. The experimental work centered around the project Salt Vault demonstration. Based on these studies, it is expected that the overall salt mass will remain intact and maintain almost all of its strength throughout the operational phase of the repository. Although movements of the roof and pillar walls are expected, support would not be required except in isolated cases.

1.4.3.2 Room Closure

Amounts of room closure have been estimated from the studies described in the foregoing paragraphs. The relative closure rates are affected not only by the thermal loading but by the mine geometry. For example, room closure is reduced significantly when barrier (buttress) pillars are used.

Room dimensions were established taking into account the amount of closure expected to occur during the developmental and operational phases of the repository. That is, if the roof and floor in a particular room were expected to converge two feet during the time period of interest, the room height was increased by two ft. plus an additional amount for a margin of safety.

1.4.4 Groundwater Movement

The shafts sunk to the repository level would most likely encounter water bearing aquifers as indicated in the generic stratigraphic section shown in Dwg. 22 in all sets. Theoretical calculations show that water would flow from the unsealed aquifers into the shafts at rates between a few hundred gallons per minute (gpm) to a few thousand gpm.⁴ (The extreme variation in the calculated inflow rates reflects the wide range of aquifer permeabilities found in nature. More exact estimates of water inflow can be established only after the specific site for the repository

has been studied and tested.) Unless the aquifers are properly sealed, the shafts would provide potential conduits for water to enter the repository. For this reason, special care must be used in the design and construction of the aquifer seals.

The repository would be constructed entirely within the salt layers. Therefore, no inflow into the repository would occur, assuming the design and layout of the facilities would eliminate the possibility of major shearing or rupturing of the rock to adjacent water-bearing strata.⁵

1.5 Repository Personnel

At times of peak mining and waste handling, the repository labor force is projected to be about 1,500 to 2,000 employees. Waste placement operations are assumed to be three 8-hour shifts, 250 days per year while all other operations are performed on a two 8-hour shift, 300 day per year basis. Personnel assignment schedules for Cycles I, II, and III are given in Tables 1-2, 1-3, and 1-4, respectively. For a Job Classification Breakdown Summary the reader is referred to Appendix B.

1.6 Mining Methodology

Continuous mining units would be used to mine the rooms and corridors in the salt repository. These machines are finding increasing application in mine layouts having relatively long rooms (4,000 ft. in length or greater).

Because of the high productivity and very long distances involved, an elaborate conveyor system would be used to transport excavated material underground. An extendible conveyor would be used to load mined salt from directly behind the mining unit onto the branch corridor conveyor. The material would then be conveyed through the branch corridor and automatically be discharged onto the main corridor conveyor which empties into a surge bin. The surge bin feeds a loading pocket and the material is then loaded into a skip for removal to the surface.

1. REFERENCES

1. Office of Waste Isolation/Union Carbide Corporation, Nuclear Division, Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies, Y/OWI/TM-36/2, Oak Ridge, Tennessee, April 1978. Part I.
2. Ibid.
3. _____, Baseline Rock Properties Salt, Y/OWI/TM-36/4, Oak Ridge, Tennessee, April 1978. Chapters 2 and 7.
4. _____, Stratigraphies of Salt, Granite, Shale, and Basalt, Y/OWI/TM-36/3, Oak Ridge, Tennessee, April 1978 Chapter 2.
5. _____, Ground Water Movement and Nuclide Transport Y/OWI/TM-36/21, Oak Ridge, Tennessee, April 1978.

2.0 SURFACE FACILITIES

2.1 Site

An area of approximately 200 acres, roughly centered on the 2,000 acre subsurface repository area, is required to accommodate the surface facilities. The relation of this surface area to the subsurface area is shown on the inset of the Site and Plot Plan Drawing (Dwg. 1 in all sets). ¹

This 200 acre area is enclosed first by an agricultural fence. A second double security fence with a 50 ft. unoccupied isolation zone provides a high security area for repository operations. The minimum distance between the agricultural fence and the double security fence is 75 ft.

The double security fencing is penetrated only by two guarded access points - one for personnel and motor vehicles and one for railroad tracks that serve the receipt of nuclear waste and miscellaneous material required for plant operation.

The buildings and facilities located inside the high security area are:

- o Canistered Waste Receiving Building
- o Low-Level Waste Receiving Building
- o Liquid Radwaste Treatment Building
- o Exhaust Ventilation Building #1
- o Exhaust Ventilation Building #2 (for 25-year retrievability with heat removal only)
- o Supply Ventilation Building
- o Boiler and Refrigeration Building
- o Site Control Building
- o Men and Material Building
- o Mine Operations Building
- o Main Power Substation
- o Emergency Generator Building
- o Diesel Fuel Tanks

- o Storage Building
- o Cafeteria
- o Laundry
- o Fire House
- o Water Tank
- o Guardhouses

Between the agricultural fence and the double security fence are the following facilities:

- o Administration Building
- o Warehouse and Maintenance Building
- o Clinic
- o Major Parking Area
- o Storage Area and Railroad Car Loading Facilities for excavated material
- o Railroad Car Dump Hopper for coal supply to the boiler house.

2.2 Buildings

2.2.1 Design Criteria

All surface buildings would be designed for standard construction, as required by local conditions and local codes except for specific critical buildings as described under the respective headings.

The various equipment and parts incorporated at the repository will be, to the greatest extent possible, manufacturer standards and off-the-shelf items. The design for the basic movement of all matter being handled either vertically or horizontally always considered equipment that would not require an engineering effort of a first time nature.

2.2.2 Canistered Waste Handling and Receiving Facility

2.2.2.1 Building Function

The Canistered Waste Receiving Building, shown in Dwgs. 2 through 4, in all sets, and in Fig. 3, would provide the facilities

and equipment necessary to receive and handle waste canisters arriving at the repository in shielded and sealed shipping casks via railroad cars.

Depending on the fuel cycle, several of the following types of canistered waste would be received at this building:

- o High-level waste (HLW) in solidified glass or calcined form
- o Intermediate-level transuranic waste (IL-TRU)
- o Cladding waste (CW)
- o Spent Fuel assemblies from Pressurized Water Reactors (PWR)
- o Spent Fuel assemblies from Boiling Water Reactor (BWR)

2.2.2.2 Building Description

The Canistered Waste Receiving Building is a two-story reinforced concrete structure - one story above grade and one below grade. The building is designed according to criteria specified in 10 CFR Part 50, Appendix A.

All areas where the canisters would be outside of a shielded cask have adequate biological shielding of conventional reinforced concrete. All activities in these areas (Transfer Cells, Canister Storage and Feed Room and Shaft Transfer Room) are remotely monitored and controlled.

The ground floor, shown in Dwg. 2 in all sets, contains a Railroad Car Washdown and Cask Preparation Shed, three (3) independent bays for Cask Unloading with confinement chambers, six (6) Transfer Cells plus one (1) Overpack Transfer Cell, six (6) Operating Galleries, the upper part of the Canister Storage and Feed Room, and the Electrical Equipment Room. Additional space is provided for support functions and activities associated with canister handling, including a lab, counting room (for counting surface dose rates from swabs), health physics office, security personnel checks, reception station, change rooms, briefing room, shift foreman's office, and service and maintenance area.

The basement floor, shown in Dwg. 3 in all sets, contains six (6) Transfer Galleries plus one (1) Overpack Transfer Gallery, working in tandem with the Transfer Cells above, five (5) Service Galleries in conjunction with the Transfer Galleries, the lower part of the Canister Storage and Feed Room with an adjoining Operating Gallery, a Mechanical Equipment Room containing air intake and exhaust filters plus intake fans, and a maintenance and service area.

A small sub-basement, also shown in Dwg. 3 in all sets, adjoins the Canistered Waste Shaft and contains two (2) Shaft Transfer Rooms.

2.2.2.3 Major Equipment

Major equipment items in the facility include:

- A. Overhead bridge cranes:
  - o Two - 10 capacity, in the Cask Preparation Shed
  - o Three - 150 ton capacity, in the Cask Unloading stations
  - o Seven - 10 ton capacity, in the Transfer Cells
  - o Two - 25 ton capacity, in the Canister Feed Room
  - o One - 5 ton capacity, in the Mechanical Room
  - o Four - 25 ton capacity, at the bottom of Canistered Waste Shaft
- B. Transfer Mechanisms:
  - o Seven - lateral cask transfer, in the Transfer Galleries
  - o Seven - lifting, in the Transfer Galleries
  - o Seven - lateral canister carrier movement, in the Canister Feed Room
  - o Two - canister basket movement, in the Shaft Transfer Rooms
  - o Two - track closures, (removable track extension) in the Shaft Transfer Rooms
  - o Four - canister basket movement, in the bottom of Canistered Waste Shaft

- o Four - track closures, in the bottom of Canistered Waste Shaft
- o One - overpack canister transfer and lift table, in the Overpack Gallery.
- c. Miscellaneous Equipment:
  - o Six - automatic cask lid unbolting and bolting machines, in the Cask Unloading Stations
  - o Six - cask washdown showers, in the Cask Unloading Stations
  - o Twenty-one - master slave manipulators, (remote mechanism for testing, inspecting and processing the canisters) between Operating Galleries and Transfer Cells
  - o Fourteen - canister washdown mechanisms, in the Transfer Cells
  - o One - automatic overpack canister lid welding machine, in the Overpack Transfer Cell
  - o Six - cask atmosphere purging and testing machines, in the Cask Unloading Station
  - o Fourteen - canister leak testing machines, in the Transfer Cells

2.2.2.4 Detailed Sequence of Operation

The sequence of handling the canistered waste, shown in Dwg. 5 in all sets, is described below in the form of a list of instructions to permit the reader to understand more clearly the handling process:

1. Pull in one or two railroad cars, with a single shipping cask aboard each, into the Cask Preparation and Washdown Shed. Test each car for surface contamination. If indicated, decontaminate the car by a washdown. Remove the cask tiedowns.

2. Move a railroad car through one of three confinement chambers and into one of the three Cask Unloading Stations, using a switch engine or a trackmobile.
3. Using a 150-ton overhead bridge crane, raise the cask to a vertical position on the car. Lift the cask and transfer it to a Cask Inspection Station.
4. Inspect the cask identification mark and compare it to the shipping documents for accounting purposes. Check for surface contamination and sample the cask atmosphere by purging and testing. By use of an automatic machine, unbolt the cask lid, without removing the lid itself. (All cask inspection, testing and unbolting will be done remotely or behind a shielded screen.)
  - a. If the cask surface passes the acceptance criteria, and the sampling of its atmosphere indicates no canister leak - pick up the cask by crane and lower the cask into one of the Transfer Galleries (normal route).
  - b. If the surface of the cask is contaminated (but contains no canister leaks) - wash and decontaminate the cask and continue as 4a above.
  - c. If the sampling of the cask atmosphere indicates canister leaks within the cask - move and lower the cask into the Overpack Transfer Gallery, washing the cask first if surface contamination is also indicated. (Note: If a cask with a leaking canister is located in one of the two outer Cask Unloading Bays - move this cask to the central bay first, through the interconnecting doors, since only this bay has the Overpack Transfer Gallery.)
5. Move and position the cask in the Transfer Gallery to line it up with a cask port in the Transfer Cell above. Lift the cask, utilizing a moving and lifting mechanism, until its neck engages the seal in the port above. The operations in the Transfer Galleries can be monitored

from the adjoining Service Galleries. (For handling of a cask in the Overpack Transfer Gallery see paragraph 10 below.)

6. Using a remotely controlled (from the Operating Gallery) 10-ton overhead bridge crane in the Transfer Cell, remove the cask lid (the bolts were removed previously) and lay it down on the floor of the cell. The same crane would remove one canister at a time and place it on a testing stand.
7. Technicians working in the Operating Galleries (at the side of the Transfer Cells), besides remotely controlling the crane in the cell, would use master slave manipulators and shielded viewing windows, to test, inspect and process the canisters in the cells. Read and compare the canister identification mark with the shipping documents. Weigh and take swabs of the canisters to test for surface contamination. Read the temperature of the surface and the radioactivity level at the surface and compare them to the repository acceptance criteria. Test for canister leaks in a special test well within the cell.
  - a. If the surface of the canister passes the acceptance criteria and there are no indications of leaks or damage - lower the canister, by use of the crane, through a small port in the floor into a carrier in the Canister Storage and Feed Room (main route.)
  - b. If the surface of the canister is contaminated (but contains no leaks or physical damage) - decontaminate the canister by use of steam in a special well located within the cell, ensuring no escape of steam into the cell which might cause fogging and impairment of the operators' vision; proceed according to paragraph 7a above.
  - c. If leaks or physical damage to the canister are indicated - place the canister back into the shipping cask, put the lid back on and move it to the Over-

pack Transfer Gallery in the central bay. (Note: In case of canister surface contamination or leaks (paragraph 7b and 7c above) the Transfer Cell itself should be checked for surface contamination and, if so indicated, washed down.)

8. After removal of all canisters from the cask (paragraph 7a and 7b above) - put the cask lid on, and send it back to the test stand in the Cask Unloading Station. Rebolt the lid (use the automatic machine), retest the surface of cask and if so indicated, decontaminate. (Note: All openings in the floor of the cell have removable plugs to prevent contamination of adjacent areas. The plugs will be removed and reinstalled as required by the process.)
9. Return the cask to the railroad car and place it in a shipping position (use overhead crane) and move it to the Cask Preparation and Washdown Shed. After a final test of the car (and decontamination, if needed) - tie the cask down and ship back to the source.
10. The cask in the Overpack Transfer Gallery (see paragraph 4c above) and the canisters in the Overpack Transfer Cells (paragraph 7c above) are handled similarly to the cask and the canisters in the regular Transfer Galleries and Transfer Cells respectively (paragraphs 5, 6 and 7 above), except for additional steps of overpacking a leaking or damaged canister in the following manner:
  - a. Move and raise an empty overpack canister, which is stored in the Overpack Transfer Gallery, to be flush with a sealed opening in the floor of the Overpack Transfer Cell above. Lower the damaged canister (by use of cell crane) into the overpack canister. Using a remote control welding machine, seal the lid of the overpack canister.
  - b. Decontaminate the overpacked canister and all the other canisters from the cask which contained the

leaking canister. Decontaminate the cell, after removing all canisters after each overpacking operation as required.

11. Move the processed canisters that were lowered into a tracked carrier in the Canister Storage and Feed Room (paragraph 7a above) laterally to the reach of one of the two 25-ton overhead bridge cranes. Pick up the canisters, one at a time, and nest them into a four (4) canister transport basket. If a backlog occurs, temporarily store the canisters in holes in the floor of the Canister Storage and Feed Room and plug; later on, retrieve and load the canisters into the four canister transport basket as above. The whole operation in the Canister Storage and Feed Room is remotely controlled from an adjoining operation gallery.
12. Lower the filled transport basket through openings in the floor into the Shaft Transfer Room, track them into a shielded cage in the Canistered Waste Shaft, and lower them to the storage level.
13. At the Subsurface Receiving Station, roll out the basket from the cage and, by use of overhead cranes, bring it within reach of a shielded transporter. The transporter removes two canisters, one at a time, and transports them together to a Storage Room for emplacement.
14. The empty basket is tracked back to the cage, brought up to the Shaft Transfer Room and then to the Canister Storage and Feed Room for further use.

2.2.3 Low-Level Waste Handling and Receiving Facility

2.2.3.1 Building Function

The Low-Level Waste Receiving Building will provide the capabilities necessary to receive and handle all low-level waste shipped to the repository in closed cargo carriers via railroad cars con-

taining drums on pallets; in addition, the facility will receive and handle loose drums with low-level waste produced within the confines of the repository and trucked to the facility.

In all cases the drums containing low-level waste would be standard size, 55 gal., Department of Transportation (DOT) type 17C, steel drums and would be contact handleable. The basic difference between the low-level waste operations and operations for canistered waste is that low-level wastes are not anticipated to require remote or shielded handling. For a process flow diagram see Dwg. 8 in all sets.

2.2.3.2 Building Description

The Low-Level Waste Receiving Building, shown on Dwg. 7 in all sets, is a single story reinforced concrete building divided into two parts: a high bay and a low bay. The high bay contains the Cargo Carrier Unloading and Storage Area and is of conventional construction, i.e., with no special seismic, nuclear, or quality assurance requirements.

The low bay would be designed for seismic loads but no biological shielding is required because the radiation level at the drum surface does not exceed allowable exposure levels. The low bay contains a transfer vehicle confinement chamber, a parking area for the loaded transfer car, an unloading area for the forklifts, depalletizing and repalletizing areas for the drums, personnel and vehicle confinement chambers, a Low-Level Waste Shaft confinement chamber, testing room, operating gallery, decontamination and overpack room, a counting room, health physics and foreman offices, a forklift battery charge room, electrical and mechanical equipment room (housing fans, filters, and electrical switchgear), men and women change rooms, and a controlled entry.

2.2.3.3 Major Equipment

Major equipment items in the facility are as follows:

- o One overhead bridge crane, 50 ton capacity in the Cargo Carrier Unloading Area;
- o One overhead bridge crane, 5 ton capacity in the Mechanical Room;
- o One tracked Cargo Carrier Transfer Car;
- o One forklift truck for pallet handling;
- o One clamp truck for drum handling (two trucks for Fuel Cycle I only);
- o Two forklift trucks for pallet handling at the bottom of the Low-Level Waste Shaft and in the storage room (one each);
- o One flat bed truck for underground transport of pallets.

In addition, spare forklift and clamp trucks are necessary to provide uninterrupted service during maintenance and repair.

2.2.3.4 Detailed Sequence of Operation

The sequence of handling the low-level waste, shown in Dwg. 8 in all sets, is described below in the form of a list of instructions to permit the reader to understand more clearly the handling process:

1. A flat railroad car arrives with two cargo carriers (similar to "Super Tiger" Type B cargo containers) aboard at the Low-Level Waste Receiving Building Cargo Carrier Unloading Area. Each carrier contains up to 42 drums on pallets. Test the car and the exterior of the carriers for surface contamination and sample the interior of the carriers. Decontaminate, if indicated, and wash down dirt and grime from the car and the carriers. Unstrap the carriers.
2. Using a 50-ton overhead bridge crane, lift one carrier and place it on the floor of the Cargo Carrier Unloading Area for temporary storage. Check the carrier identification mark and compare it to shipping documents for accounting purposes.

3. Move the transfer car (which is self-propelled) with the carrier aboard through the confinement chamber and into a parking spot in the Pallet Unloading Area.
4. Open the end doors of the carrier and, by means of a battery operated forklift truck, remove the pallets (one at a time) from the carrier and deposit them in the Depalletizing Area of the Transfer Room.
5. Meanwhile, the transfer car with the empty carrier is sent back to the Cargo Carrier Unloading Area. The empty carrier is picked up by the crane, loaded onto the waiting railroad car and strapped down. The full carrier is then lifted from the temporary storage on the floor, and loaded on the transfer car which is moved to the Pallet Unloading Area.
6. In the depalletizing area a clamp truck removes one drum at a time from the pallet ("depalletizing") and transfers it to the Testing Room.
7. In the Testing Room the drums are identified (compared with shipping documents), weighed and tested for surface contamination and leaks. The radioactivity level at the surface is measured and compared to the repository acceptance criteria.
  - a. Drums that have sufficiently low surface contamination are taken by the clamp truck to the Repalletizing Area where they are repalletized.
  - b. Drums that have excessive surface contamination or show an indication of leaks, are moved by the clamp truck to the Decontamination and Overpack Room, where they are decontaminated (the leaking drums are first overpacked) and then moved by the clamp truck to the Repalletizing Area for repalletizing as in paragraph 7a above.

8. The reassembled pallets are moved, one at a time, by a forklift truck to the Low-Level Waste Shaft where they are lowered to the storage level. The pallets are then taken to the Storage Room and stacked two high.

2.2.4 Radwaste Management and Facilities²

Radwastes that result from the operation of a waste isolation facility would take the form of solids, liquids and particulate matter in gases. The primary sources for these radwastes include:

Solids. Combustible items such as paper, rags, plastic sheeting, protective clothing, gloves, rubber shoes, wood and filter cartridges and noncombustible materials (concrete, mortar, etc.), small discarded equipment, metal filters and metal encased HEPA filters.

Liquids. From railroad car and cask decontamination, laboratory drains, laundry drains, shower rooms, building and equipment decontamination, personnel decontamination facilities and chemical wastes from the chemical make-up area.

Gases. Fine suspended radioactive particulate matter in vent gases, building ventilation system and gases from the incineration process.

2.2.4.1 Solid Radwaste Treatment

Solid waste from all sources would be sorted at the points of origin and segregated as follows: Noncombustible materials would be collected and packaged for eventual size reduction by compaction and disposal in drums; combustible wastes would be burned in an incinerator with the resulting waste ash collected in drums for disposal.

The compactor system would compress noncombustible material such as residue from the incinerator or used high efficiency particulate air (HEPA) filters directly into 55-gal. drums. The compaction/drumming process can be operated remotely from the control room. The required approximate capacity of the compaction system is estimated to be 150 drums/month.

2.2.4.2 Decontamination Procedures

The decontamination of rooms, casks and equipment would be accomplished by high pressure steam with remote and manual operation for the high and low radiation levels, respectively. Local decontamination of casks can be achieved by wiping. The resulting liquid waste in each building would then be collected locally in each building in a storage tank through pipe drains. Radwaste generated at the storage level as a result of clean-up operations for an accidental spill would be collected there in drums and transported to the surface through the Low-Level Waste Shaft. A 3,000 gal. tank in a concrete vault would be located adjacent to each of the following building facilities: the Low-Level Waste Receiving Building; Canistered Waste Receiving Building; Exhaust Ventilation Building; and the Liquid Radwaste Treatment Building. These tanks would receive the locally collected liquid radwaste and, depending on measured radioactivity, would feed one of four 10,000 gal. tanks in concrete vaults located outside the Liquid Radwaste Treatment Building. The contents of these four tanks would be sampled and monitored for effluent disposal or processing through the radwaste treatment system.

2.2.4.3 Liquid Radwaste Treatment and Facilities

2.2.4.3.1 Building Description

The Liquid Radwaste Treatment Building would contain all the tanks and equipment necessary for collecting, storing, treating, and solidifying liquid radioactive waste generated on the site. The plan for this building provides separate rooms for the concentrator, ion exchange systems, solidification systems and access for trucks to bring in empty drums and chemicals and to carry filled drums on pallets to the Low-Level Waste Receiving Building for storage processing. Space is also provided for guarded check-in of personnel, change room, wash rooms, and supervision room.

Arrangement of this building is the same for all fuel cycles.

2.2.4.3.2 Liquid Radwaste Treatment Process

A schematic flow diagram of the liquid radwaste management system is shown in Dwg. 16 in all sets. Liquid radwaste would be generated in five major areas including: the Canistered Waste Receiving Building, the Low-Level Waste Receiving Building, the Exhaust Ventilation Building with its solid waste incineration and compaction facilities, the Liquid Radwaste Treatment Building, and in the subsurface storage areas.

To minimize the need for treatment of the liquid waste, an effort would be made to separate the drainage collection system into two areas: those where contamination is certain to occur and those where the chance of contamination is only slight.

The probability of high contamination would occur in those areas where unshielded waste materials are handled or decontaminated, namely, Canistered Waste Receiving Building, the incineration compaction facility, and various areas of the Liquid Radwaste Treatment Building. In the remaining areas, the chance of contamination of house cleaning elements is much reduced and liquids would be collected merely as suspected waste.

The waste of known contamination and the suspect waste would be collected in each area in two separate tanks and from these tanks pumped in separate double contained pipelines with leak test capability to two 10,000 gal. tanks each for contaminated and suspect waste. The contamination of the liquid would be monitored. Contaminated waste would be pumped to the concentrator feed tank. Suspect waste would be pumped in one of three paths depending on the degree of contamination: if clean, into one of two clean water holding tanks; if only mildly contaminated, to an ion exchanger; if contaminated, to the concentrator feed tank.

The clean wastes can be disposed of in several ways: either re-used for decontamination, discharged into an evaporation pond, or boiled off or fog sprayed into the exhaust stack of the Exhaust Ventilation Building.

The waste to be treated would be pumped into the concentrator system where the volume would be reduced. The vapors would be condensed, and the condensate cooled and further treated in ion

exchangers. The residual matter from the concentrator would be pumped to a holding tank for solidification with cement. The ion exchange effluent would be monitored in catch tanks and either pumped to the clean water tanks or recirculated through the concentrator system. The spent resin would also be treated through the concentrator system.

All tanks and condensers would be vented under negative pressure by a steam jet into a condenser; the condensate is treated as contaminated waste, and the off vapor is heated, filtered through two HEPA filters, and exhausted to the atmosphere.

The following is recommended for the liquid radwaste treatment system for this facility:

System handling capacity approximately equal to 300 gal./hr.

Concentrator system and condenser to handle 900 gal/hr. for 8 hr./day

Steam supply = 3,000 #/hr. at 50 psig

Concentrator reduction factor = 25 to 1

Concentrator feed tank = 2,500 gal/ (7'-6" Dia x 8')

Condensate tank = 2000 gal.

Concentrate Tank = 500 gal.

2 - 18" Dia. by 6.0' ion exchangers at 7.5 gpm each

2 - 300 to 350 gpm cooling tower operating from 85⁰

F to 105⁰ F, size 14'-3" x 7'-3 1/2" x 8'-3" each

4 - 10,000 gal. waste tanks (14'-0" Dia x 10' each)

2 - 10,000 gal. clean effluent receiving tank (14'-0" Dia x 10').

The liquid radwaste solidification system would use cement as a solidification agent, and the solid radwaste would be packed in DOT type 17C, closed-top, 55-gal. drums with 4-in. diameter caps.

Components of the system are: (1) cement filling station, (2) holding tank, (3) drumming station, (4) bridge crane, (5) control console, and (6) drum inspection and labeling station. The system handling capacity would be about 12 gal./hr.

In operation, cement brought to the site would be unloaded into the cement storage silo. The silo and drum loading system

would be a closed, dust-free system with its own bag-type dust collector. Empty drums from storage would be transported on a roller conveyor to the filling location. The radwaste material, in the form of a slurry, would be piped in double contained pipes with leak test capability to the holding tank where the liquids and solids would be properly proportioned for mixing with the cement. After the operator determines the proper mix, an automatic cycle would be started that would uncap the drum, then fill, mix, and recap it. This would be done on the safe side of the shielding wall.

The drum would then be moved by crane to the inspection station where it would be weighed and the radiation level measured prior to being transported to the Low-Level Waste Receiving Building.

2.2.4.4 Gaseous Waste Treatment

Each of the four critical buildings, the Low-Level Waste Receiving Building, Canister Waste Receiving Building, the Liquid Radwaste Treatment Building, and the Exhaust Ventilation Building, has a separate vent system filtered by a multistage filtering system. The type of filters and their characteristics are determined by the potential radioactive content of the circulation route. Operation of the system would be within its specified operational limits of flow, pressure drop and other parameters at all times. The air would pass through three stages-pretreatment, prefiltration and high efficiency filtration-before being exhausted.

All exhaust air would pass through prefilters before it passes through the high efficiency filters. The prefiltration would remove large concentrations of particles (1 micron) and thus protect the more efficient, and therefore more easily plugged, HEPA filters downstream. The prefilters would be constructed of panels of vertically pleated fiberglass and encased in rigid cases similar to the HEPA filters described below. When dust loaded, the entire unit would be removed and replaced.

High efficiency filtration will be done with HEPA filters having an efficiency of 99.9% for 0.3 micron particles when tested

with a monodispersed 0.3 micron thermally-generated, diotyle phthalate (DOP) aerosol. The maximum clean filter pressure drop would be 1.0 in. of water at rated flow capacity.

The filter would have a core of continuous web fiberglass pleated with aluminum separators; the rigid frame would be of corrosion resistant steel. All exhaust effluents would be passed through two HEPA filters in series before being released to the atmosphere. Used HEPA filters would be compacted and disposed of as noncombustible solid waste.

Testing would be done in-place, and the design includes ports for injection of testing agents and for extraction of samples. The design also includes access for testing personnel with radiation shielding, lighting and life support systems to adequately protect personnel and expedite the work. Individual testing of multiple filters in close proximity would be accomplished by built-in or temporary bypass ducts and shrouds.

The system with two HEPA filters in series would have a total decontamination factor (DF) of 1×10^6 . This would be verified by DOP or Freon Testing in accordance with ANSI N510.

2.2.4.5 Control of Radwaste Systems

The atmosphere in all rooms of the Liquid Radwaste Treatment Building would be monitored on a continuous basis. Substances to be monitored include alpha- and beta-emitting particulates and beta-emitting gases. Three ambient gamma-monitors with two of three alarm logics are assumed to be in operation at all times in each room. This provides maximum monitoring, with assurances against false alarms. The incineration and compaction room of the Exhaust Ventilation Building has a similar system. In each of the two waste receiving buildings, duplicate beta-particulate and beta-gas monitors analyze the vent discharge air downstream of the filters at all times. Liquid waste in the storage tanks would be continuously monitored with gamma- and alpha-sensitive liquid monitors.

All controls for operation of the radwaste treatment systems are located in a control room with secured separate outside access. This control room is assumed to have an independent HVAC system. The entire system is designed to be equipped with a closed loop video system to provide the operator with views of all rooms and operations in the building. All remote handling and automatic cycling originates in the control room. Alphanumeric and graphic displays of all data from the radiation monitors are provided to the operator as well as transmitted to the central control station.

2.2.5 Exhaust Ventilation Building #1

Plans and sections of the Exhaust Ventilation Building are shown in Dwgs. 10, 11, and 12 in all sets.

For the 5-year retrievable repository and the 25-year retrievable repository without heat removal, this building will house the exhaust fans and filters required for continuous filtering of the exhaust air from the subsurface waste placement operations as well as the exhaust fans associated with the mining and drilling (or trenching) operations. For the alternative 25-year retrievable case with heat removal, a second Exhaust Ventilation Building will perform the latter function. Building #1 also contains space for incineration and/or compaction of site-generated solid radwaste.

Exhaust air from the filters would be discharged through a 100-ft. high stack. Handling of filters and fans would be accomplished by two overhead cranes.

2.2.6 Exhaust Ventilation Building #2

The design for a Cycle II, 25-year retrievable repository with waste heat removal includes a second Exhaust Ventilation Building. This building will completely handle all exhaust air from the mining and trenching operations.

The fans for normal operation are located above-ground and exhaust directly to the atmosphere through evase stacks. However, the building is equipped with emergency filters and fans that will exhaust through a 100 ft. high stack.

2.2.7 Supply Ventilation Building

This building will house the fans that supply ambient air for the mining and placing operations, heating coils for possible preheating of the mine supply air and filters for the intake air.

A layout of this building is shown for each respective cycle in Dwg. 14 in all sets.

2.2.8 Boiler and Refrigeration Building

The steam generating equipment and the refrigeration equipment will be housed in separate sections of the building. The boiler plant will be complete with coal-fired stoker furnaces, boilers, coal storage handling and weighing system, condensate handling, water treatment and feedwater systems, and effluent treatment systems.

Furnace flue gases will pass through a dust collector and a scrubber prior to discharge through the boiler stack to meet EPA regulations on dust and gaseous pollutant emissions. Ash from the dust collector and the stokers will be collected in the ash storage bin before final disposal.

The refrigeration plant includes water chillers, chilled water and condenser water pumps, cooling towers, chemical water treatment systems, and local motor control center area. Heating and ventilation are provided for the refrigeration plant to meet minimum summer and winter design conditions.

2.2.9 Central Site Control and Switchgear Building

This building will house the following facilities:

- o A central control room for remotely controlling and monitoring the ventilation equipment in the Exhaust and

Supply Ventilation Buildings, monitoring all security instrumentation and monitoring radiological readouts for all critical areas.

- o A communication room
- o A guard room
- o A mechanical room for services for this building
- o A switchgear room for control of the equipment in the Exhaust and Supply Ventilation Buildings
- o A garage for security personnel use
- o Ancillary facilities such as offices, lounge, conference rooms, locker and shower rooms.

The arrangement of this building is the same for all cycles.

2.2.10 Men and Material Building

This building provides separate personnel facilities such as locker rooms and showers for the mining crews and the placing crews, as well as briefing rooms, check-in, and control facilities. It will also provide covered access to the Men and Material Shaft Headhouse for personnel, equipment and materials.

2.2.11 Mine Operations Building

Adjacent to the Men and Material Building, a Mine Operations Building will be provided for use of the mining contractor.

2.2.12 Main Substation

The main power substation will be an outdoor installation (without shelter surrounding it).

2.2.13 Emergency Generator Building

This building will house the diesel turbine-driven emergency generators.

2.2.14 Diesel Fuel Tanks

Diesel fuel for the diesel driven emergency generators and

the mining and placing operations will be stored in three below-grade 15,000 gal. capacity storage tanks. A pump system will fill the day tank for the diesel turbines of the emergency generators. Fuel oil for the mining and placing operation will be lowered to the mine level either in drums or tanks on the men and material hoist.

2.2.15 Storage Building

This building will provide intermediate storage between the warehouse located outside the isolation fencing and short-term requirements of the plant operations. It is accessible by truck and railroad for shipments from outside.

2.2.16 Cafeteria

The cafeteria will be located within the high security area to obviate security checks of the personnel during lunch breaks. The cafeteria will be serviced by a local caterer and will operate for each shift.

2.2.17 Laundry

The laundry building will be equipped to clean work clothes of the mining personnel and personnel other than those engaged in areas where radiological contamination may occur, such as the Canistered Waste Receiving Building, the Low-Level Waste Building, and the placing operations. The clothing for these personnel will be of the disposable type and will be incinerated for emplacement as low-level waste.

2.2.18 Fire House

The fire house will be equipped with pumpers and other fire fighting equipment.

2.2.19 Water Tank

An elevated water tank will provide storage of approximately 150,000 gal. capacity for fire fighting emergencies.

2.2.20 Guardhouses

A guardhouse is located at the entrance for personnel and motor vehicles. It will provide all facilities for checking, controlling, and monitoring all personnel, cars, and trucks entering the high security area. It will also contain an alarm and communications system integrated with the security system of the central site control building.

A second guardhouse at the entrance of the railroad tracks would serve to monitor and control all rail traffic into and out of the high security area.

2.2.21 Administration Building

The administration building, located outside the high security area, will house all administrative operations for the repository such as accounting, auditing, computer, contracts, insurance, mail-room, payrolls and purchasing.

2.2.22 Warehouse and Maintenance Building

Materials will be received at the warehouse and maintenance building, also located outside the high security area, thereby allowing deliveries by truck or rail to enter and leave without elaborate security checks. Material required inside the high security area will be removed from its packaging as far as possible, checked and forwarded to the storage building inside. All refuse cartons, or other packaging material will thus remain outside and can be disposed of through ordinary means. The maintenance building would be equipped with tools and machines for minor repairs and maintenance. Major repairs are expected to be performed by outside contractors.

2.2.23 Clinic

The clinic is located outside the high security area to permit outside ambulance service to operate without delay caused by security checking. First aid and emergency treatment will be performed in the clinic.

2.3 Major Parking Area

This area is also located outside the high security area to avoid having to check every car. It will have sufficient parking space for personnel for two shifts.

2.4 Railroads

The railroad track work is arranged so that nuclear waste material handling, excavated material disposal, and coal handling will be separated in their respective areas to minimize security checking of equipment and personnel. The design of the track work serves the following purposes:

- o Receipt of nuclear waste shipments, transfer to the Canistered Waste and Low-Level Waste Receiving Buildings and return of empty casks and shipping containers: Sufficient trackage is provided within the high security area for two days of shipments and outside this area for ten days of shipments. Transfer from over-the-road locomotive to plant switch engine is assumed to take place at the guarded entrance.
- o Receipt of shipments for warehouse and mine operations: Trackage is provided so that these shipments can be moved directly to a warehouse located outside the high security area without take-over by plant engines, or into the high security area by transfer to plant engines in a manner similar to the handling of nuclear waste shipments.
- o Disposal of excavated material: A railroad loop outside the high security area allows over-the-road locomotives

to bring in trains of empty cars to the loading station and remove loaded trains to an offsite disposal area.

- o Receipt of coal shipments: A track parallel to the excavated material loop allows receipt of coal for the boiler plant.

All repairs to over-the-road railroad equipment will be performed by the carrier. Minor repairs to yard equipment will be performed on-site. Major repairs will be assigned to outside contractors.

2.5 Materials and Supplies - Receiving and Handling

Materials and supplies are assumed to be received either by railroad or trucks at the warehouse located outside the high security area where they may be stored, uncrated, and checked. They are then to be taken to the storage building inside the high security area by on-site trucks, as required. Alternatively, materials and supplies can be brought directly to the storage building and yard storage inside the high security area by truck or rail if appropriate security procedures are followed.

2. REFERENCES

1. Office of Waste Isolation/Union Carbide Corporation, Nuclear Division, Drawings for Repository Preconceptual Design Studies: Salt, Y/OWI/TM-36/9, Oak Ridge, Tennessee, April 1978.
2. _____, Nuclear Considerations for Repository Design, Y/OWI/TM-36/21, Oak Ridge, Tennessee, April 1978. Section 5.0.

3.0 UTILITIES

3.1 Domestic Water

Potable water for the facility would be supplied to the site from two sources to minimize the chance of supply interruption. A storage tank would provide emergency water reserves on site.

3.2 Electric Power

3.2.1 Power Sources

The primary source of electric power for the facility is assumed to be from overhead medium voltage lines of a local electric utility company. It is expected that a facility total demand load would vary between 20 and 30 MVA depending on the fuel cycle (See Table 3-1). In the event of complete failure of the primary source, electric power would be supplied to critical equipment and loads by a secondary power source consisting of an on-site limited capacity generating plant. This generating plant would provide alternate power by diesel electric generators having their own fuel supply. During the interim period between loss of primary power and the availability of secondary power, uninterrupted power supply would be provided by motor generator sets with flywheel or battery powered converter-inverter systems.

3.2.2 Primary Electric Power

The primary electric power is assumed to be purchased from the utility company at a locally available medium voltage from 23,000 to 69,000 volts and transformed down to a distribution voltage of 13,800 volts. Primary power would supply interior and exterior lighting, ventilation equipment for mining and nuclear waste placement operations, surface waste handling and support facilities, motorized equipment for surface building HVAC requirements, radiation monitoring instrumentation, telephone and radio communications

systems, security and surveillance systems and alarms including closed circuit television, hoists, mining operations and conveyors, repository waste placement operations and maintenance and repair of equipment.

3.2.3 Electric Services

Two electric services would be provided, each normally supplying half of the total facility load as shown in Dwg. 20 in all sets. Each service voltage would be transformed to the distribution voltage by a dual rated transformer located in the main substation as shown in Dwg. 21 in all sets. Appropriate interconnecting high voltage switching would permit connection of both transformers to a remaining service in the event of failure of one of the services. Each of the main service transformers would be provided with sufficient redundant capacity through forced air cooling to permit supplying up to 93% of the facility load through one transformer.

3.2.4 Distribution

Each main service transformer secondary winding would connect to a sectionalized 15 KV switchgear bus through a main secondary power air circuit breaker. The sectionalized bus would be interconnected by a bus tie circuit breaker.

Several 15 KV feeders would connect to the sectionalized bus and supply various loads throughout the facility at a nominal voltage of 13,800 volts. Essential loads such as waste processing buildings and mine ventilation would be supplied by dual feeders terminating in double ended load centers. Other loads would be supplied by single feeders. Each of the dual feeders would have sufficient capacity to supply the total load of a double ended load center in the event of failure of one of the feeders. Similarly, transformers and primary and secondary circuit breakers of double ended load centers would have redundant capacity to supply the total load-center load.

3.2.5 Utilization Voltages

Utilization voltages would be 4,160 volts, 480 volts, 277 volts, and 120 volts. Motors rated at 450 hp and larger would be energized at 4,160 volts. Motors rated at 1/2 hp to 400 hp would be supplied at 480 volts. Building fluorescent lighting would generally be supplied at 277 volts. Incandescent lighting and convenience receptacles would be fed at 120 volts. Outdoor perimeter security lighting would be on a series 6.6-ampere circuit as would be the roadway lighting. Security lighting would be on an emergency circuit.

3.2.6 Underground Distribution

All wiring between origin and destination of different buildings is designed to be installed in underground conduits and man-holes. Three separate conduit systems would be used. One system would contain wiring for telephone communications, security and alarm wiring, fire alarm wiring and CCTV wiring and cables. The second system would contain power and control wiring originating at the emergency electric power generating plant. The third system would contain power, lighting and control wiring of the normal primary power source supply and distribution. Power to the mine for mining and placement operations would be supplied by exposed insulated 13.8 KV cables installed in the utility compartment of the Men & Material Shaft. In the mine, exposed insulated cables be suitably attached to the wall and, through skid-mounted mining-type power centers at predetermined locations, would supply power to mining equipment as well as placement, service, and repair equipment.

3.3 Sanitary Waste Disposal

The sanitary waste treatment and disposal system would collect and dispose of all non-contaminated waste and sewerage from the surface facilities in an on-site treatment system. (Refer to section 2.2.4 for a discussion of contaminated waste treatment.)

3.4 Fuels

Coal and diesel oil would be the only fuels stored on the site. Coal would be used for the steam boilers and oil would be

used for diesel operated trucks and for emergency electric power generators.

Daily diesel oil requirements for underground activities would be transported in approved portable tanks. The emergency diesel electric generators would have an oil supply that is separate from all other uses. .

3.5 Steam

The steam is used for three major purposes: General Building Heating (35%); Process Usage (45%); and Underground Ventilation Supply Air Tempering (20%).

Steam at 200 PSIG is assumed to generated by four coal burning boilers. Each boiler would have a capacity of 50,000 lbs./hr. for a total capacity of 200,000 lbs./hr. Steam would be routed through the utility tunnels to each building or area where service is required. At each building the steam pressure would be reduced to low pressure (under 15 PSIG) or as required for process service.

3.6 Refrigeration Plant

Five steam-driven chilled water refrigeration machines, with a capacity of 250 tons each, would serve the facility. Four refrigeration machines would operate and one chiller would serve as a standby. The machines would be either of the steam drive absorption type or the steam drive turbine open centrifugal type.

The refrigerant condensing water would be cooled by water towers. The chilled water would be routed to the various buildings through the utility tunnel.

3.7 Emergency Utility System

3.7.1 On-Site Power Generation

In the event of the failure of both primary electric services, on-site power generating capacity, as shown in Dwg. 21 in all sets, would be provided to supply the requirements of essential loads.

This includes power for: limited mine ventilation while evacuating mine personnel, radiation monitoring instruments, communications and security systems, maintaining essential underground and surface facility processes, fire alarm and protection systems and the Men and Material (M&M) hoist system serving the men working below ground.

Three or four units, each rated at 1000 KW, 1250 KVA, 0.8 power factor, would be provided depending on the ultimate requirements for essential load. Each of the several units would have the capability of being connected to one of two distribution busses. One bus would be exclusively connected to the M&M hoist during an emergency. The other bus would connect to the remaining essential emergency load. Once a generating unit is preselected and connected to the exclusive M&M hoist bus the other units would be permitted, through appropriate interlocks, to be connected only to the other bus serving the remaining essential load. One of the units would be a reserve unit in the event any other of the preselected units fails to start upon command.

3.7.2 Uninterruptable Power Supply

During the interim between the failure of the primary power source and the availability of the secondary generator power source there are currently only two requirements anticipated for uninterrupted power at the repository. The first is for sufficient lighting to aid personnel to exit from structures and for operating personnel to start alternate power equipment if manual starting is required. The second requirement is for sufficient power to maintain the continuity of operation of radiation monitoring equipment, communications, security operations, central control station, guard house operations and control instrumentation among all of the principal facilities of the repository.

Essential and critical equipment that requires power continuity would be supported by localized uninterruptable power supplies consisting of a rectifier, battery and inverter. Complete lighting blackout would be precluded by the installation of self-contained battery powered emergency lighting units which would provide sufficient lighting for orderly egress from structures.

3.8 Communications

Normal communications between or within the various areas of the repository, both surface and subsurface facilities, are assumed to use commercial telephone lines. In addition, each guard or watchman on duty would have the capability of maintaining continuous communications with an individual in a continuously manned central alarm station. The secondary alarm station would be located at the guard house adjacent to the personnel portal. The primary communication link between a roving guard and the central and secondary alarm stations would be by dual-channel walkie-talkie. A secondary guard communication link would be by strategically located telephones with exclusive guard access and connected to the central alarm station by dedicated lines. This secondary link would serve a two-fold purpose as it would complement procedures for frequent status reporting and serve indirectly as a duress alarm to verify the safety of patrolling personnel.

The central alarm station would have the capability of calling for assistance from other guards or by prior arrangement from the local law enforcement authorities. Two-way radio and conventional telephone service would be provided for this capability. All communications equipment would remain operable after loss of primary power by automatically switching to an uninterruptable supply and then to the on-site alternate generator system.

4.0 MINE-OPERATING AND WASTE-RECEIVING SHAFTS IN SALT

4.1 General Description

In these designs, five distinct shaft structures would be sunk using conventional techniques. These shafts are the Canistered Waste Shaft, the Low-Level Waste (LLW) Shaft, the Men and Material (M&M) Shaft, the Ventilation Supply Shaft, and the Ventilation Exhaust Shaft. The orientation of the shafts as well as their basic characteristics, such as size, method of construction and design, varies according to their purpose and the influence of constraints upon the mine and shaft network construction schedule. The shaft construction schedule is given in Dwgs. A32, B31, C32, D31, and E34. Shaft descriptions for these repository designs are shown in Table 4-1.

In the study being considered, five shafts are to be excavated from the surface to the repository horizon. Because the placement schedule would be delayed if the underground initial development had to wait until the permanent Men and Material Shaft was operational, efforts were directed toward developing a construction plan that would promptly provide a temporary shaft facility with: (1) an excavated material hoisting capacity of 2,000 TPD; (2) the capability of lowering a maximum load of 20,000 pounds; and (3) sufficient space to deliver 100,000 cfm of fresh air. The plan selected to satisfy these requirements is to sink one of the shafts from the surface using the "Blind Hole Drilling Method," which is faster than conventional shaft sinking. (See Section 4.4.) The shaft to be bored would be the LLW Shaft which, because of its small diameter, can be bored the fastest. The four remaining shafts are to be excavated using conventional drill and blast techniques. Basic shaft information is contained in Table 4-2.

4.2 Shaft Descriptions

4.2.1 Canistered Waste Shaft

The Canistered Waste Shaft is designed to provide a means for transporting canisters from the Canistered Waste Receiving

Building at the surface to the subterranean storage levels. This shaft has an inside diameter of 14 ft. and is lined with a minimum of one (1) ft. of concrete except where aquifers are encountered. At such interfaces extra measures, such as steel liners and grout, would be used to control water inflow. The top of the shaft forms an integral part of the Canistered Waste Receiving Building. Both the surface and subsurface receiving areas associated with this shaft and the shaft itself are divided by a wall to provide two identical but independent means of transporting canistered waste. The waste is lowered in the shaft with a Canistered Waste Cage. The Canistered Waste Shaft is shown in Dwgs. A34, B33, C34, D33, and E36.

In a repository for reprocessed waste (Cycles I and III), the Canistered Waste Shaft provides access to the intermediate and cladding waste storage area at one elevation and to the high-level waste storage area at another elevation. From shielded receiving stations at these two elevations, the canisters may be transferred to shielded transporter vehicles for transport to the storage sites. The loading and unloading of the waste canisters into and from the Canistered Waste Cage used in the Canistered Waste Shaft would be handled by remote control.

In a SURF (Cycle II) repository, the shaft provides access to the BWR fuel assembly storage area at one elevation and to the PWR fuel assembly storage area at a lower elevation. Receiving stations and handling operations at each of these levels are anticipated to be similar to those for HLW in the reprocessed waste repository.

The desirability of using a shielded cage for moving the canistered waste between the surface and subsurface facilities is problematical. Although a shielded cage would permit easier access in case of accidental derailment of the cage within the shaft, the shielding would increase the cage weight substantially. However, the total lifting load is considered to be within existing mine practice. In contrast, the alternative to a shielded cage would be to use an unshielded cage and provide for a means whereby

a disabled cage could be assisted either by remote operation from one of the shaft entrances or by personnel using a specially designed shielded repair cage. These remote handling devices and special repair vehicles are unique; they would require research and development and involve a continuous modification program based on accident experience, whereas the shielded canister cage would not. The Canistered Waste Cage is shown in Dwgs. A35, B34, C35, D34, and E37 and the Canistered Waste Safety Mechanism is shown in Dwgs. A36, B35, C36, D35, and E38.

4.2.2 Low-Level Waste Shaft

The Low-Level Waste Shaft would provide a means for transporting low-level waste pallets from the low-level waste surface facility to the low-level waste subterranean storage area. This shaft has an inside diameter of 10 ft. and is lined with a minimum of one ft. of concrete except in aquifer strata where extra measures will be incorporated, such as steel liners or grout. The shaft is shown in Dwgs. A37, B36, C37, D36, and E39.

4.2.3 Men and Material (M&M) Shaft

A Men and Material Shaft would handle mine and storage personnel and mined material removal. The shaft is designed to satisfy three requirements:

1. Provide access for personnel and equipment into and out of the subterranean storage areas.
2. Provide excavated material hoisting for the mining operation.
3. Serve as a utility access shaft and manway for emergency exit by all personnel.

To meet these requirements the M&M shaft is divided into three main compartments (personnel and equipment cage, excavated material hoisting skips, and a manway and utility access space) and two auxiliary compartments for skip counterweights. The shaft has an inside diameter of 27 ft. and a minimum of one ft. thick concrete liner, except in water bearing strata where extra measures described above would be incorporated.

The personnel and equipment compartment for the shaft is designed to be sufficiently large to accommodate a double-deck cage with a capacity for 140 men. The mining and placement crews would use different levels so that task crews remain separated. The compartment also is large enough to permit the lowering and raising of large pieces of equipment either in assembled or partly disassembled form. In the heat removal case of Cycle II, additional supply air is brought down through the M&M Shaft at a relatively low velocity for subsurface ventilation. This helps reduce the load on the Ventilation Supply Shaft. The M&M Shaft is shown in Dwgs. A33, B32, C33, D32, and E35.

4.2.4 Ventilation Supply Shaft

Ventilation air for the underground areas would be received through this shaft. (See Dwgs. A41, B40, C41, D40 and E43.) Prior to receipt, the air is anticipated to be processed in conformance with air quality and temperature requirements. The shaft, as designed, is lined with a one ft. minimum layer of concrete. Ventilation Supply Shaft dimensions are given in Table 4-1.

4.2.5 Ventilation Exhaust Shaft

Ventilation air from the subsurface areas would be exhausted through this shaft into filtration systems located on the surface. The shaft would be concrete lined and divided so that mine and placement exhaust air can be processed separately if there is no evidence of contamination. Inside diameters of the exhaust shafts for various repository designs are shown in Table 4-1. Two exhaust shafts are required for the special heat removal case for Cycle II, 25-year retrievability. A cross-section of the exhaust shaft is shown in Dwgs. A42, B41, C41, D41, and E44.

4.2.6 Service Shaft

A second additional shaft would be required for the Cycle II (twenty-five year retrievability) heat removal case only. This Service Shaft would be used to transport the hollow precast concrete cylinders and base slabs that are to be installed in the storage trenches prior to canister placement. The shaft has an inside

diameter of 17 ft. and a minimum one ft. thick concrete lining. It contains a skip approximately 7-1/2 ft. by 13 ft. for hoisting the materials. A cross-section of the shaft is shown in Dwg. E45.

4.3 Conventional Shaft Sinking Techniques¹

Once the construction contract has been awarded and clearing of the construction site completed, mobilization of the shaft sinking contractor's equipment can begin. In the conventionally excavated shafts, the bottom of each shaft would be advanced using a bench method. In this method, hand-held drills are used to drill holes over one half of the shaft area. The holes are loaded with explosives and the rock blasted. Alternate halves of the shaft are drilled and blasted to advance the entire shaft bottom.

The broken rock would be cleaned from the bottom using a cactusgrab mucker dumping into buckets. These buckets are hoisted to the surface and dumped at the headframe into a bin. On the surface, the broken rock is transported by truck from the headframe bin to a rock disposal area.

Prior to sinking into the aquifers, a grouting station would be excavated at the bottom, outside the perimeter of the shaft. From this station, vertical holes would be drilled to intersect the water-bearing zones. As these zones are intersected, a cement or chemical grout would be pumped from the surface into the water-bearing formation. In this manner, a grout curtain would be formed around the perimeter of the shaft. This would prevent excessive amounts of formation water from entering the shaft excavation so that the sinking can proceed safely and expediently.

Depending upon the stability of the shaft walls, 40 ft. to 60 ft. of shaft would be advanced before lining with concrete. Concrete will be mixed on the surface and lowered to a receiving hopper on the sinking stage. From the receiving hopper the concrete would be distributed to liner forms through large diameter hoses.

While sinking through the water bearing zones the diameter of the excavation is enlarged and a "preliminary" one ft. thick concrete lining would be poured-in-place. Once the excavation has fully penetrated the aquifer a concrete bearing ring and steel wedge ring would be installed at the bottom of the water bearing zone. (See Dwgs. A44, B43, C44, D43 & E47). Working from the steel wedge ring upward to the top of the aquifer a permanent steel lined concrete hydrostatic liner would be installed and grouted in place to make the shaft watertight.

After the shaft has been excavated to its final depth, the final grouting of any water leaks in the lining would be accomplished. This procedure, called drywalling, ensures that the lining is competent and watertight.

4.4 Shaft Boring Techniques - Blind Hole Drilling Method²

As mentioned previously, it was decided to bore the LLW Shaft from the surface to its final depth - 2,000 ft. - in order to allow initial development to start at an earlier date than would be possible using conventional sinking techniques.

Both the equipment and method used for drilling shafts are highly specialized. Shaft drilling differs from ordinary rotary drilling in the manner in which force is applied to the bit and in the technique used to remove the cuttings.

In order for a rotary bit to cut a hole, the required bit force must vary directly with the square of the hole diameter in order to maintain drilling pressure. Thus such a shaft requires large downward forces. Drilling pressure is maintained by adding heavy "parasite" weights to the drill string immediately above the bit. These parasite weights are cast iron "donut-shaped" sections that fit around the drill string. These sections can be added or removed as required.

Drill cuttings are removed by a method called "reverse circulation air lift". Using this method, the drilling fluid is added to the annular space and the cuttings are removed up the inside of the drill string (reverse of ordinary rotary drilling).

The selection of correct drilling muds and the amount to be used is a specialized field of engineering which has been developed in the oil well drilling industry. While drilling the LLW Shaft, the drilling mud would initially consist of sodium bentonite clay. From the anticipated flow of water, it has been estimated that mixtures up to 11 pounds of bentonite per gallon of water would be required. Once salt is encountered, the mud composition would be changed by the addition of Attapulgate clay. This would prevent the bentonite clay from losing its swelling characteristics which occurs when it comes in contact with a salt brine.

Upon completion of the drilled hole, the drill rods, weights and bit would be removed from the hole which is left full of drilling mud.

The next step consists of installing the steel liner. The liner provided is a hydrostatic liner designed to resist the total static head of water at all depths in the shaft. The shaft liner is prefabricated in 10 ft. high sections consisting of an outer shell of cold rolled mild steel strip plate of varying thickness and an inner lining of concrete one ft. thick and varying in strength from 3500 psi to 6000 psi.

Following installation of the lining, the permanent headframe and hoist would be constructed. Initially, the shaft would be equipped to permit hoisting a 10-ton skip in balance with a counterweight. A solid brattice wall would divide the shaft allowing it to be used for fresh air and exhaust air. These arrangements would be used to permit mining from the LLW Shaft until the M&M Shaft has been excavated and equipped to permit its use for mining. At that time, the LLW Shaft would be converted to its final use. This would involve removing the 10-ton skip, counterweight and brattice wall, re-arranging the guides and installing the LLW cage.

4.5 Lining

Since one of the requirements of for the repository is that the shaft be completely dry, and since it will be desirable at some time in the future to abandon and decommission the underground

facility, it must be protected in such a manner that there is no possibility of contaminating the groundwater. Therefore, the shaft linings are designed in the aquifers to be completely watertight and capable of withstanding a full hydrostatic head with a safety factor of 2.5.

In the excavated shafts the lining generally consists of 3500 psi concrete, one ft. thick. Any water seeping through this liner is collected in water rings and directed through vertical piping, cast into the concrete liner, to the shaft bottom. During construction, this water would be hoisted with the sinking buckets. Once the shafts are completed, this water can be directed to the main pumps and pumped to the surface.

The bored shaft is to be lined with a steel liner for its entire length. The liner consists of cold rolled mild steel plate from 3/8 in. to 1-1/4 in. thick and an inner lining of 12 in. thick concrete, having a compressive strength of 3500 psi to 6000 psi. The installation of this lining is explained in Section 4.4.

Specifications for the hydrostatic liners in the different aquifers are given in Table 4-3.

4.6 Water Control Techniques

As mentioned previously, the principal difficulty to be overcome when excavating the shafts is the heavy water flows expected to be encountered in water-bearing aquifers. In order to overcome these problems, the following techniques would be used.

4.6.1. PregROUTING

Prior to excavating through the aquifers, a grout station would be excavated at the bottom of the shaft. Vertical holes are drilled and cement or chemical grout is injected into the water-bearing formations to form a grout curtain around the area to be excavated.

4.6.2 Lining

In the excavated shafts a double-wall steel and concrete hydrostatic lining would be placed through the entire depth of each aquifer. This liner includes a pigotage to prevent water migration along the liner.

The bored shaft would have a steel hydrostatic liner throughout its entire length. A 12 in. thick concrete liner would be poured on the inside face of the steel liner.

4.6.3 Drywalling

Following excavation of the entire shaft, time has been allotted to permit grouting any water seepage that may occur through the liner.

4. REFERENCES

1. Office of Waste Isolation/Union Carbide Corporation, Nuclear Division, Facility Construction Feasibility and Costs by Rock Type, Y/OWI/TM-36/18, Oak Ridge, Tennessee, April 1978. Section 4.1.2.1.
2. Ibid, Section 4.1.2.2.

5.0 MINING AND WASTE PLACEMENT OPERATIONS IN SALT

5.1 Design Criteria

Several criteria must be considered when developing a layout for the subsurface portion of the repository. The following are of prime concern:

- o The size of the room opening must be compatible with both the mining equipment to be used in order to avoid special machinery as well as with the proposed waste placement scheme. Room sizes must also be designed with consideration to clearance requirements of the waste transporter.
- o The pillar size must ensure adequate heat dissipation into the geologic medium and must also ensure overall mine stability.
- o The mining schedule must make storage rooms available for waste placement by early 1985. This requirement includes excavation of the rooms, trenching or drilling of holes, and installation of canister sleeves. Subsequent storage rooms must be completed in time to permit receipt of incoming waste.
- o Mining and waste placement operations must be kept separate from each other for reasons of safety. This necessitates allowing entries for waste placement that are isolated from those used for mining, and the sequencing of each of the operations to avoid crossovers.
- o The extent of underground development must not exceed 2000 acres. (See Section 2.1)
- o All shafts must be located in a central area for reasons of security. Also, the shafts must be in the same relative positions for each cycle in order to make possible the use of similar surface layouts for each of the cycles.

5.2 Mine Layouts

Room dimensions and configurations were determined, based on the above criteria, for each of the fuel cycles. Mine Master Plans are shown as Dwg. 25 in each of the fuel cycle drawing sets (A,B and C). Extraction ratios are shown in Fig. 5. Room and corridor details are shown in Dwgs. A28, B27, and C28.

Two basic configurations are presented for the storage room layout in Cycle I. In the first, used for storage of IL-TRU, CW and LL-TRU, the storage rooms connect directly to the main corridors (Dwg. A25) at right angles. They are grouped into panels (repeating patterns of rooms and pillars) of four rooms per panel and are 3150 ft. long, except for the first panel. The first panel is shorter (1575 ft.) so that it can be completed in time to receive waste in 1985. Rooms within a panel are separated by a 30 ft. wide yield pillar designed to carry most of the overburden load of a panel. Successive panels are separated by a more massive buttress pillar 78 ft. wide. The room openings are 36 ft. wide by 20 ft., resulting in an extraction ratio of 46%. (See Dwg. A28). This "long room" system provides for relative ease of operation and high mining efficiency. Also, the yield and buttress pillar sequence increases the overall mine stability and decreases the susceptibility of the rooms to shear failure, while significantly reducing the room closure rate.

The second scheme, which would be used for HLW storage, provides a number of "branch corridors" perpendicular to the main corridors. Storage rooms, each 560 ft. long, 18 ft. wide and 20 ft. high, extend from the branch corridor at right angles (See Dwg. A28). A branch corridor and its adjacent rooms constitute one panel. Each panel has 40 rooms. Mining this "short room" system is more difficult and less efficient than the long rooms. However, the short rooms permit a greater flexibility of waste placement and increased control over the dissipation of heat as required by the special nature of the high-level waste canister.

The 20 ft. room height would easily accommodate the waste transporter, which is about 16 ft. high. Room closure due to creep

is assumed to reduce the ceiling height by two ft., leaving an additional two ft. of clearance. Approximately 90% of the closure occurs within five years after the opening is completed.

Both layout configurations allow for the separation of the mining exhaust air from the canister placement exhaust air. The mining exhaust air in the short room system is taken back to the branch corridor (separated from the supply air by a line brattice) then ducted to the closest completed room in the same panel. It then travels from the end of the room to the main corridor system by way of the branch exhaust corridor. Similarly, in the long room system, mining exhaust air is directed back to the main corridor and finally to the Ventilation Exhaust Shaft. In both systems, air from the placement operation is designed to be directed outward to a perimeter exhaust corridor and back to the Ventilation Exhaust Shaft.

The layout for Cycle II utilizes the long room system for both types of spent fuel (PWR & BWR) as well as for low-level waste. (See Dwg. B25). Because of the heat generated by the spent fuel canisters, a lower extraction ratio (25%) was used as compared to the IL-TRU in Cycle I. The yield pillars are 45 ft. wide and buttress pillars 80 ft. Room openings are 18 ft. wide by 22 ft. high (see Dwg. B27). The 22 ft. high ceiling is required to allow for a 19 ft. high transporter, 2 ft. of creep and 1 ft. additional clearance.

The Cycle III layout (Dwg. C25) is identical with Cycle I except for a smaller number of LL-TRU panels, reflecting a smaller ratio of LL-TRU to HLW when Pu is not reprocessed.

The layouts for all three cycles satisfy the requirement of 150 KW per acre maximum allowable local areal thermal loading. Actual thermal loadings are shown in Table 5-1. The thermal loadings for the spent fuel canisters (Cycle II) are significantly less than the maximum allowable because of physical restraints that preclude canister spacings of less than six ft. on center. Also shown are the assumed heat generation rates for the various waste types at time of arrival at the repository.

A summary of room dimensions and capacities is shown in Table 5-2. In the first column, the year in parentheses is the approximate year that the repository reaches capacity, according to the waste receiving schedules (Tables 5-3 through 5-8).

5.3 Mining Operations

Drill and blast mining methods are usually selected for mining in thick salt deposits for reasons of cost and productivity. Salt is abrasive to continuous mining units and therefore maintenance costs are high. However, conventional drilling and blasting would not be employed for mining operations in the storage areas because of possible blasting damage to the facility. No blasting would be required after the proposed starting date of the repository operation, and only a limited amount would be required prior to the receipt of waste units.

The mining operations would be performed using electrically powered continuous mining units that cut an opening 11 ft. high by 18 ft. wide.¹ If the mining machine cuts a second pass beside an initial entry, a room with dimensions 11 ft. high by 36 ft. wide would be created. If two more passes are made later in the floor, the room produced would have dimensions of 36 ft. by 20 ft., suitable for IL-TRU and CW storage. Thus a total of four machine passes is required. For these 20 ft. high rooms, the floor cutting would cause unbalanced pressures on the mining machine rotors and, therefore, increased maintenance costs. For the 18 ft. wide rooms, two passes are required, resulting in 20 ft. high ceilings (HLW) or 22 ft. high ceilings (spent fuel). If the spent fuel waste transporter is 20 ft. high instead of the 19 ft. high assumed, an additional 1 ft. would have to be mined out from the storage rooms, resulting in a room cross-section of 18 ft. by 23 ft.. The extra mining pass would reduce the mining production rate and increase costs significantly.

In order to achieve efficient mining, at least three development entries or "corridors" are needed. Four main corridors would

be used in each repository, serving the following functions: one to emplace waste; one to carry the mined salt conveyor; one to serve as a travelway for mining equipment, trucks, and personnel; and one to carry exhaust air from the mining operation. The main conveyor is assumed to be suspended from the ceiling, thus allowing additional mining equipment to travel through this corridor. Supply air flows through all mining corridors that serve as travelways for men and equipment.

Extendible conveyor systems that receive the mined salt directly behind the mining machine and transport the material without secondary handling are strongly preferred in many mining applications because of high productivity and low operating cost. Such a mining scheme would be used for the long room systems of each cycle. The extendible conveyors in each room would transfer the salt to roof-suspended main line conveyor systems that transport the salt to a 6500-ton underground storage bin. A reclaim conveyor beneath the storage bins is fed by vibratory feeders that are automatically controlled. The salt is held in a surge bin prior to being conveyed to loading pockets for hoisting to surface. (See Dwgs. A26 and A27).

In the short room system, however, the constraints on mine geometry are such that the loader and truck method, which is more flexible, would be used for the mining operation. Trucks will transport the mined salt from the rear of the continuous mining machine to the branch corridor conveyors which would be frequently extended so that truck haulage distances are maintained as short as possible. The branch corridor conveyors then transfer the salt to the main line conveyor.

Electrically-operated trucks could be used in the rooms, but the haulage distances are fairly long for trailing cables, and trolley wire systems are not practical for continuous mining systems. Therefore, diesel trucks would be used for this operation. Normally, two trucks operate behind one mining unit, but often in restricted areas only one truck can operate efficiently. On very long hauls three or more trucks may be used.

Support facilities for mining operations would be located in a central area near the M&M Shaft. Access to all mining areas is provided from the central service area, which would include a communications center, a warehouse and large mechanical and electrical shops, a parking area, a tool room, and a communication center. This location is most suitable to provide efficient service for all mine areas and would have the least heat effect from the storage areas.

5.4 Initial Development

An assumption of five years between the start of construction of the first shaft and the receiving of the first shipment of waste has been made for design purposes. During this time a number of operations must be completed, including the sinking of all shafts, excavation of a service area for assembly, maintenance and repair of mining equipment, and the installation of the main conveyor system. In addition, a mined material handling system, consisting of a 6500 ton storage bin, a 1000 ton surge bin, and conveyors which would transport the material to the M&M Shaft, needs to be installed to ensure efficient mining production. Lastly, at least one panel in each of the waste type areas would be mined and ready to receive the incoming waste units.

In order to initiate mining as soon as possible, the first 1.5 years of mining would be through the LLW Shaft since this shaft can be completed in about half the time required for the M&M Shaft. A temporary hoisting system would be installed in the LLW Shaft and a salt handling system developed at the base of the shaft for use during this period. The temporary hoisting system would have a capacity of about 2000 tons per day. This corresponds to two machines each mining 1000 tons per day. During this time air for ventilation would be ducted back through the LLW Shaft. When the M&M Shaft is completed, mining operations would gradually switch to this shaft. Mining and hoisting capacities would then increase significantly. The following is a tentative schedule for the in-

initial development stage of the repository. The schedule is roughly the same for all three cycles. The start of construction is taken as time 0.0.

Year

0.0	All shaft construction commences.
1.5	LLW Shaft completed; temporary hoisting and salt handling system installed in LLW Shaft.
1.5-3.2	Two mining machines in operation, approximately 2000 tons/day total; mining service area completed; mined material handling system installed; main line conveyor system completed; Ventilation Supply Shaft and Ventilation Exhaust Shaft completed.
3.2	M&M Shaft completed.
3.2-5.0	Four mining machines in operation, approximately 6000 tons/day total; Canistered Waste Shaft completed; all corridors in the central area are mined; approximately 30% of exhaust corridors are mined; one panel in each of the three waste storage areas are mined; holes drilled and sleeves installed in the completed panels.

5.5 Excavation of Rooms

As mining continues past the initial development stage, production rates peak and remain fairly constant throughout the life of the repository. In the spent fuel (Cycle II) repository, four mining machines are operated simultaneously. Each machine mines approximately 2000 tons per day, yielding a total output of 8000 tons per day. For Cycles I and III, where the short room system is utilized, peak production per machine is 1500 tons per day. A maximum of five machines operate simultaneously, resulting in a daily mined output of 7500 tons. Peak mining production figures are summarized in Table 5-9.

Mining production rates were computed assuming two working shifts per day and 300 working days per year. If production should fall behind schedule, a third shift could be initiated. Also, for each

four or five mining machines in operation an additional one would be required as a spare so that major overhauls can be routinely performed on each machine in turn. It is probable that one or two mining machines would need replacement after the first ten years.

The panel numbers shown in each of the Mine Master Plans (Dwg. 25 in all sets) signify the sequence in which the panels are mined for each storage area. Immediately after completion of the mining in each panel, drilling of the canister holes would commence. Placement of the canister sleeves for the first five years of operation would follow the drilling and in some cases would be done simultaneously with the drilling in the same panel (but not the same room) because of the time constraints. Dwgs. 23 and 24 on all sets show the approximate time periods allotted to each operation for each panel.

Equipment and personnel associated with the mining, drilling and sleeve placement operations would travel through the middle two M&M corridors. Transporters carrying the waste canisters would travel through the main corridor closest to the Canistered Waste Shaft. Placement of waste canisters would follow the same panel sequence as the mining operation. The sequence of panels is such that the canister placement operation need not cross any of the other operations. There will be a period of from two months to four years between the time of panel completion (holes drilled or sleeves installed) and placement of the waste canisters. It is more efficient to have a steady mining rate, which results in these time gaps, than to adjust the mining rate to the waste receiving schedule. Table 5-10 shows a breakdown of the mining tonnages for each cycle.

5.6 Drilling

Following the excavation of the rooms, storage holes would be drilled into the floor for all waste types except low-level. Storage holes would be drilled no less than six ft. apart to avoid fracturing the floor of the storage room. Drilled holes, rather than trenches, are used because they permit a more efficient storage configuration under the thermal loading criteria. Because the hole depth exceeds or nearly exceeds the room height, the drilling

would be done in a multistage operation, using a two-piece drill bit. The drilled cuttings would be handled by front-end-loaders or large scooptrams which would carry them to the main conveyor. The number and spacing of holes varies between waste types due to allowable thermal loadings and the optimization of the floor plan -- one row spaced 10 ft. longitudinally for HLW and 5 rows spaced 6 ft. for IL-TRU and cladding, to illustrate the two extremes.

For Cycles I and III the depth of the storage hole is 20 ft. and for Cycle II the depth of the hole is 25 ft. These different depths reflect different canister heights for each cycle. (See Table 1-1.) The diameter of the holes drilled for Cycles I and III is 22 in. when a sleeve is used. For Cycle II PWR waste with protective sleeve, the hole diameter is 24 in. and the BWR hole diameter is 20 in. If no sleeve is used all these diameters can be reduced by 2 in. It is estimated that one crew can drill approximately 3 to 4 holes per 8-hour shift.

Table 5-9 shows the maximum number of drilling crew-shifts per day.

5.7 Sleeve Emplacement

The purpose of the sleeve is to maintain retrievability by maintaining the integrity of the hole from creep and the integrity of the canister from corrosive influences. In salt, a 3/8 in. thick sleeve of mild steel is placed into the hole prior to waste placement. The sleeve size corresponds to the dimensions of the canister. Its outside diameter is 16 in. for Cycles I and III, 18 in. for Cycle II PWR and 14 in. for BWR. The length of the sleeve is approximately 18-1/2 ft. for wastes in Cycles I and III and approximately 23-1/2 ft. for wastes in Cycle II. The sleeves are sent down the Men and Material Shaft in sections of two and positioned into the drilled hole. At the top of the sleeve a segmental flange is used to support the concrete plug. A small amount of backfill may be required between the sleeve and the drilled

hole to ensure that the canister would remain plumb during the placement process and throughout the retrieval period. Sleeve placement would be provided only during the retrievability period (assumed in these studies to be five years).

The IL-TRU waste and cladding waste would be emplaced in five rows of holes drilled 6 ft. on center between rows, and 6 to 6-1/2 ft. on centers in the longitudinal direction. Since the IL-TRU and CW canisters generate a negligible amount of heat, the minimum spacing of approximately 6 ft. is used. The HLW canisters would be placed in single rows, and spaced 9 to 10 ft. longitudinally (See Table 5-2). These spacings are based on the allowable heat loading and heat generation per canister. (See Dwgs. A31, B30, and C31 for details of the canister storage.)

5.8 Subsurface Waste Receiving and Placement Operations

Subsurface receiving and placement operations originate at the subsurface Canistered Waste Receiving Station, a tri-level underground facility capable of safely handling the material under shielded control conditions. The three distinct levels -- lower, intermediate and transporter level -- serve separate functions in the material flow process.

The canistered waste would first arrive at the lower level in baskets of up to four units each. A section of moveable rail, part of an elevated rail, would bridge the gap to the canister waste cage. The basket would move out onto this rail until it aligns with a remotely operated port in the ceiling above. The port would open and allow a moveable bridge crane to hoist the basket up into the intermediate level. The port would then close, and an empty basket which is queueing on the elevated rail would immediately be loaded into the cage to return to the surface for refilling. The lower level thus acts as an exchange room for empty and full baskets of waste canisters.

After the full basket has entered the intermediate level, one of two procedures would be followed: The bridge crane may locate the basket directly below the loading port for transporter

loading or it may transfer the basket off to the side if temporary surge storage is required. Thus the intermediate level provides isolation between the unloading of the cage and the loading of the transporter. The transporter level accommodates the final stage in the subsurface receiving operations before the waste is taken to a storage room. This level provides two independent loading areas for the transport vehicles and queueing space for additional vehicles. Each loading area has a remotely operated port opening to the intermediate level below.

Canisters placed by the moveable crane would be removed from the basket into the transporter shielded container by hoisting devices on the transporter. The transporter operator would position the vehicle over the loading port in the floor of the transporter level, seal the space between the vehicle and port, open the port, lower independently operated hoisting devices down from within the shielded chamber and lift two canisters, one at a time, from the basket below. The remaining two would be taken by the next transporter. Once the canister is within the shielded loading chamber of the transporter, the chamber and loading port would be closed, the seal removed and the transporter would reposition the shielded chamber to an inclined position (to lower the center of gravity) for transport to the storage room. A cut-away perspective of this operation appears as Fig. 4.

The transporter would then proceed through the isolation doors to a designated storage room at approximately 5 mph. Once in the room the vehicle is positioned over an empty storage hole, and the chamber is repositioned erect. Instrumentation on the transporter would permit the operator to adjust alignment of the chamber with the floor opening. The chamber door slides open and a canister is lowered down into the storage position. The hoist then is disengaged and retracted. The placing of the second canister would be similar. A possible configuration for retrievable canister storage in salt is shown in Dwgs. A31, B30, and C31.

During the five year retrievability period, the transporter would be equipped to emplace a concrete plug; otherwise, the floor

opening would be backfilled with excavated material using a support vehicle. These vehicles would be in constant communication during the placement process. After placement, the transporter would return to the subsurface receiving station for another set of canisters.

An estimate has been made of the number of transporters required during the peak year as well as at the five year intervals starting with 1985. To make this estimate, the average speed of the vehicle was taken as 5 mph. This is the conceptual operating speed of the vehicle; it may in fact be as high as 10 mph. The 5 mph figure was introduced to include an allowance for delays due to turning, brief breakdowns, etc. For each year, the approximate location of storage for the waste units was determined and the distance from the shaft to this point was found. Using this distance and the average speed of 5 mph, the time required for the transporter to travel from the shaft to the storage hole was determined; the total cycle time was taken as twice this time plus 30 minutes, which accounts for receiving and depositing of the waste canister. This cycle time was used to calculate the number of transporters required assuming 6.5 work hours per shift, 3 shifts/day and 250 working days/year.

A maximum of 5 vehicles would be required for the total placement operations. This figure does not vary between cycles. Additional vehicles would be needed as spares. In a final design, the underground storage procedure would have to be simulated in detail using queuing theory to ensure that the requisite number of vehicles could be accommodated.

In handling of low-level waste, a cage would lower pallets of drums to the subsurface facility. A forklift vehicle would be used to remove the pallet from the cage and place it on flat bed truck to be transported to the storage room. At the storage room the forklift type vehicle would place the pallet in its final storage position. The pallets measure 4 ft. wide by 6 ft. long by 7 ft. high, each containing 12 drums (2 levels of 6 drums). They

would be stacked against each wall of the room in Cycles I and III, leaving a center aisle 24 ft. wide. In Cycle II, where the rooms are 18 ft. wide, pallets would be stacked against one wall, leaving a 14 ft. wide corridor (See Dwg. 28 in all sets.) For the anticipated low receipt rates only two forklift vehicles are necessary: one in the storage room and one at the bottom of the shaft.

5.9 Backfilling

Upon a decision to cease retrievable storage (assumed to be after the fifth year of repository operation), the storage rooms filled with waste would begin to be backfilled. From that point on, rooms may be backfilled as soon as they are filled with canisters. Also, sleeves would not be required for emplacement of subsequent waste canisters.

Material for backfill would initially be provided by freshly mined salt from storage rooms being excavated concurrently. The salt would be transported by conveyor. Since the waste placement operation would always occur in a panel between the panel being backfilled and the panel being mined, a crossover results. This problem is solved by installing a conveyor that traverses the waste placement corridor from the ceiling, a common mining practice. Thus, the waste placement operation is not affected by the backfilling operation. Mined salt that is not needed for backfilling continues along the main corridor to the M&M Shaft.

After the excavation of rooms has ceased, salt for backfill would be taken back down the M&M Shaft and by conveyor to the room being backfilled. The hoisting and conveyor systems would have features enabling them to accommodate such a reversal of operation. Prior to decommissioning, all corridors would also be backfilled.

Approximately 60% of the mined salt would be returned as backfill. This figure results from the assumption that the rooms can be backfilled up to a height 2 ft. below the ceiling and the unit weight of loose salt -- 89 pounds per cubic foot. (Salt in place

is 135 pounds per cubic foot.) The mined salt not used for backfill must be dealt with in some manner. Table 5-9 summarizes the mining and backfill tonnages. The on-site storage tonnage is taken as 60% of the material mined from the rooms that accommodate the first five years of waste placement.

5.10 Decommissioning of Underground Facilities

After all wastes have been emplaced or retrieved, and decommissioning of the facility has been directed, backfilling of all remaining subsurface openings (corridors) would commence. Material for the final backfilling would come from surface storage to the extent possible. The excavation sequence would be reversed and material would be returned to the subterranean openings via the excavated material hoist in the M&M Shaft. Mining equipment deemed to be useful would be removed, dismantled, crated where required, and transferred to other sites. Shafts would be sealed in a manner to be determined by further studies.

5.11 Twenty-Five Year Retrievability of SURF

The possibility of using a subsurface storage facility for interim storage of spent unprocessed fuel (SURF) assemblies was examined, with a retrievability option for 25 years after placement. Should a decision be made to reprocess SURF assemblies stored in a repository, it would be necessary to recover them and transport them to a reprocessing facility without undue hazard. Subsequent to reprocessing, the HLW from these assemblies could then be returned to the facility for terminal storage. At that time, there would probably be no need to provide for 5-year retrievability, since the concept would have been validated by the earlier storage period for spent fuel assemblies.

The primary areas of concern in the event of waste retrievability are that the storage room openings allow accessibility for canister retrieval and that the canisters themselves remain intact. The first area requires analysis of possible room closure prior

to the end of the retrieval period while the second addresses the issues of internal stresses, temperatures and corrosion characteristics of the SURF canisters during the retrieval period.

Two approaches have been investigated that appear to accomplish 25-year retrievability: (1) reduction of the local areal thermal loading and (2) removal of sufficient heat from the storage area to permit retrievability. These two approaches are discussed in the following paragraphs.

Note that, in these analyses, "25-year retrievability" means that each canister is retrievable for at least 25 years from the date of its own emplacement. Table 5-11 summarizes the room sizes and capacities for 25-year retrievability. Alternative canister emplacement schemes for 25-year retrievability are discussed in Appendix C.

5.11.1 Reduced Local Areal Thermal Loading

Table 5-1 shows the maximum allowable local areal thermal loadings that will ensure room and pillar stability for at least 25 years. In these cases the only change in design from those for the 5-year retrievability case is that the height of the storage rooms in the salt repository has been increased from 22 ft. to 25 ft. to allow for the additional predicted creep. It is conceivable that other design changes such as stress relief slots in the ceilings of the storage rooms or variations in buttress and yield pillar dimensions could raise the thermal loading limits for the 25-year retrievability case, but these have not been evaluated here.

The average thermal loading restrictions for a 2000 acre repository are not modified by the 25-year retrievability requirement since these restrictions are dictated by a long-term, far-field consequences of waste storage. However, the allowable local areal thermal loadings are reduced considerably from the values for the 5-year retrievability case. To ensure 25-year retrievability, the maximum local areal thermal loading is 36 kw/acre instead of 150 kw/acre. The consequence of the local loading restriction for 25-year retrievability results in reduced repository capacities.

The canister stress temperature and corrosion effects are difficult to estimate. However, it is anticipated that the most serious internal thermal stresses would be encountered within the first year of emplacement for these wastes since the temperatures in the immediate vicinity of the canisters peak within this time frame.

The stresses may lead to accelerated corrosion of the canisters, especially in a salt repository where the heat may cause brine migration and radiological genesis of hydrochloric acid. This accelerated corrosion might be mitigated through either of two techniques: (1) protection of the canisters with sacrificial sleeves or (2) supporting the canisters out of contact with the formation material. To ensure 25-year retrievability, it is estimated that 1-1/2 in. steel sleeves would be required, compared with the 3/8 in. sleeves required for 5-year retrievability.

To allow for additional creep in the salt formation during a 25-year period, the storage room design height has been increased from 22 ft. to 25 ft. This creep stems from the normal pressures of the repository overburden and is accelerated by the heat flowing out of the repository. The 25 ft. height necessitates a third pass with a smaller continuous mining machine after the first two passes of 11 ft. each. The increased room height corresponds to an additional six million tons of salt that must be handled and disposed of or stored. All other repository dimensions will remain the same.

The Mine Master Plan for a 25-year retrievable repository with reduced local areal thermal loading is shown in Dwg. D25. Details of the shaft locations and corridor arrangements are illustrated in Dwg. D26.

5.11.2 Heat Removal Through Continuous Ventilation

An alternative to the case of reducing the number of canisters in the repository in order to lower the local heat loading and ensure 25-year retrievability is to remove a portion of the generated heat from the repository by continuous ventilation. This

way, the capacity of the repository need not be reduced as much as that for the previous case. However, the repository capacity is still limited because the total heat generated in the repository cannot exceed the limits by the long-term effects. Moreover the amount of heat removal is limited to the capabilities of the ventilation system which must be sufficient to reduce the thermal load to the maximum allowable for 25-year retrievability.

The Mine Master Plan for such a repository is shown in Dwg. E27. Shaft and corridor details are presented in Dwg. E28. The differences between this design and the one for the non-heat removal case are the increased air flow and the continuous ventilation of the rooms for 25 years - not just during placement or retrieval operations. Canisters will generate 60 kw/acre locally but 40% of this heat will be removed by the ventilation system to lower the effective local areal thermal loading to 36 kw/acre.

Because of their lower heat generation rate the BWR spent fuel, canisters can deliver only 41 kw/acre even at their minimum spacing. Therefore, for these wastes, it is more economical to increase the spacing from the minimum by a small amount, resulting in a thermal loading similar to the non-heat removal case above. That is, the areal heat loading becomes 36 kw/acre for the BWR spent fuel canisters and does not require ventilation for heat removal. Thus, only the PWR spent fuel storage area is ventilated for heat removal.

Shown in Dwg. E32 and E33 are concepts for the placement of the PWR & BWR canisters, respectively, in the salt repository. This model incorporates trench storage of the canisters. The concept increases the amount of potential heat removal by means of free convection from around the canister. The canisters are provided with a 3/8 in. sleeve and encased in concrete pipe. The pipe provides support of the canister and isolation from the formation material as well as a path for convective circulation for heat removal. To provide lateral bracing of the storage unit, a grid system would be installed at the trench surface.

5. REFERENCES

1. Office of Waste Isolation/Union Carbide Corporation, Nuclear Division, Facility Construction Feasibility and Costs by Rock Type, Y/OWI/TM-36/18, Oak Ridge, Tennessee, April 1978. Section 5.2.

6.0 VENTILATION SYSTEMS FOR FACILITIES IN SALT

6.1 Subterranean Ventilation Systems

6.1.1 Ventilation Requirements and Criteria

The ventilation of the mining operation and of the subterranean waste storage rooms represents a complex, challenging requirement. The changing amounts of ventilation required, as well as the gradual changeover of successive portions of the underground rooms from active excavation to long-term storage, means that the ventilation system demands a special flexibility not usually required either of simple mines or of conventional waste processing facilities.

The basic purpose of the mine ventilation system is to protect the mine personnel and the public from excessive exposure to radiation and mining dust and to provide an adequate supply of clean, fresh air for human needs and equipment requirements. Protection from excessive radiation exposure is ensured by arranging the ventilation system so that the airflows for mining activities and for waste placement are separated and by providing for filtration of all air that may have come in contact with the stored nuclear waste. The method of separation of airflows and the provisions for filtration of waste placement air are described in Sections 6.1.4 and 6.1.5.

Adequate supply of fresh air is required to satisfy breathing air supply needs and to control the chemical and physical quality of the mine atmospheric environment by providing for the removal of contaminants such as engine exhaust gases, dust, heat, moisture, and smoke generated by equipment and mining processes. Reversibility of fans would be provided if required by applicable federal and state regulations.

Ventilation criteria for this repository have been selected to provide for airflow ventilation that would comply with all existing statutes of the U.S. Bureau of Mines, Mining Enforcement and Safety Administration (MESA) or the strictest state regulations, and will include:

- o Minimum of 200 cubic feet per minute (cfm) of fresh air for each man underground;

- o Minimum of 125 cfm per brake horsepower of diesel-powered equipment;
- o Minimum of 50 cfm per square ft. of headings (or 50 linear ft. per minute of air velocity in entries);
- o 40,000 cfm of fresh air per mining machine (based on existing practice in potash mines).

The above criteria are considered to be sufficiently conservative and yet reasonable for the preliminary estimate of ventilation requirements for mining and placement operations.

6.1.2 Underground Ventilation Supply Air

Underground ventilation air would be provided by multiple supply fans located in the Supply Ventilation Building. The conceptual layout of the building is shown in Dwg. 14. The ventilation for the entire repository would be achieved in stages to correspond to the staged mining process. At the peak of the mining and storage activities in the 5-year retrievable repository designs, six centrifugal fans in parallel would supply a total of 1,450,000 cfm (Cycles I and III) or 1,300,000 cfm (Cycle II) ventilation air underground. Two additional fans would be provided as back-up units to facilitate maintenance and/or repair without interruption of the air supply. The supply fans would have inlet vane control for efficient volume control capability. (Ventilation provisions for 25-year retrievable repository designs are described in Section 6.3.) Typical supply (and exhaust) fan specifications are presented in Table 6-1.

Outside air would be drawn into the Supply Ventilation Building through air intake louvres (equipped with bird screen) and 30% NBS efficiency air filters. During cold weather, temperature of the supply air would be maintained at minimum 40°F by heating coils located in the air intake plenum. Motorized shut-off dampers would be provided in the discharge of each supply fan. The sub-surface supply air would be monitored by a flow switch which would trigger an alarm if the air flow is reduced below a pre-set minimum due to fan failure or other causes.

Air discharged into the supply air plenum would travel down the concrete-lined air supply shaft. At the base of the ventilation shaft, the airflow would be divided into separate supply air systems by controlling dampers. A throttle in each of the main supply branches would permit the ventilation air supply to be shut off in case of fire. The distribution of the supply air would be as follows:

- o Approximately 100,000 cfm would be provided for ventilating the underground M&M station and the maintenance shop and for control of dust at the storage bins and loading pockets.
- o Approximately 200,000 cfm would be supplied into the canistered waste placement corridors and the low-level waste placement corridor for the ventilation of placement operations.
- o An estimated 45,000 cfm would be required for ventilation of the subterranean waste receiving stations (25,000 cfm for the high-level waste receiving stations and 20,000 cfm for the low-level waste receiving and loading area).
- o The remaining, major portion of supply air would be used to satisfy ventilation requirements of the mining operations such as boring, drilling of waste placement holes, sleeve placement, and backfilling. At the peak of the mining and placement operations this portion of the ventilation supply air would be approximately 1,100,000 cfm for Fuel Cycles I and III, and 950,000 cfm for a Fuel Cycle II repository.

Estimated total ventilation airflow requirements at the peak of mining and placement operations are shown in Table 6-2.

6.1.3 Ventilation of Mining Operations

Proper distribution of the ventilation air to the working areas would be accomplished through the use of stoppings, doors, air locks and crossings in the main airways, and line brattices and auxiliary fans at the working faces. The conceptual layout

of the subterranean ventilation system is shown on Dwgs. A19, B19 and C19 for the 5-year retrievable case.

All corridors and rooms would be mined by continuous mining machines in multiple passes. During the mining of the first pass, effective dust removal from the working face of the mining machine would be ensured by locating the exhaust tube inlet of the portable ventilating fan as close to the cutting head of the machine as possible. The fan would exhaust the dusty air through the reinforced flexible tubing and discharge it into the main corridor serving exclusively as a mine exhaust air corridor. Additional lengths of ducting would be added as required by the advancing mining machine.

During the second pass in mining of a storage room, the exhaust air need not be returned through the same room as described above, but could be allowed to travel past the working face to the perimeter exhaust corridor and exhausted by an auxiliary fan through the adjacent, already mined, storage room. In this manner, if the ventilating fan is installed in the already mined room, the repeated extension of the exhaust tubing is not necessary. In order to avoid mining into an active exhaust corridor, in some areas an auxiliary perimeter exhaust corridor would be provided.

Drilling of holes and placement of sleeves for the canistered waste would be ventilated the same way as described above for the second pass mining operation, i.e. supply air would flow through the entire room where the work is in progress, and would be exhausted through the adjacent unoccupied storage room into the mining air exhaust corridor.

The storage rooms would be backfilled after the 5-year retrievability period. Since the backfilling would start at the end of the storage room adjacent to the periphery ventilation airway and proceed in a retreating manner toward the main corridors, ventilation would be provided the same way as during the first pass of mining of the storage room, described earlier in this section. Through redirection by a system of bulkheads, air from the mining operation would not interface with air from the backfill operation until both are vitiated.

All exhaust from the various mining operations and from the maintenance shop area would be collected by the mining air exhaust corridor. The exhaust corridor would be separated from the supply air carrying M&M corridors by well-sealed stoppings. Air lock type access would be provided to the exhaust corridor at intervals required by mining regulations. At places where the exhaust air corridor crosses entryways used by men and equipment, the exhaust air would pass above the M&M corridor through an aerodynamically shaped overcast. The exhaust air corridor would be connected to the mining exhaust compartment of the Ventilation Exhaust Shaft, through which the air would travel to the surface and would be exhausted to the atmosphere as described in Section 6.1.5.

6.1.4 Ventilation of Placement Operations

Ventilation flow rates for placement corridors and storage rooms where the placement is in progress would be as determined by the ventilation criteria described in Sec. 6.1.1. For canistered waste placement operations the governing criterion is the air requirement for the diesel engine powered waste transporters, approximately 40,000 cfm of fresh air per transporter. For low-level waste placement operations, where forklift-type vehicles would be used to place the palletized drums, ventilation would be determined by the minimum air velocity required in the occupied corridor or storage room. In a 36 ft. x 20 ft. low-level waste storage room this amounts to 36,000 cfm. Total volume of the ventilation air for the canistered and low-level waste placement operations is estimated to be 250,000 cfm, with four canister waste transporters operating simultaneously (including exhaust air from the subterranean waste receiving stations).

Placement of the canistered or low-level waste would begin at the end of storage room adjacent to the periphery ventilation drifts and proceed in a retreating manner toward the placement corridor. The ventilation air, supplied through the placement corridor, would flow through the storage room and would be exhausted through the periphery ventilation duct system. (See Dwgs. A19, B19, and C19.) This way, the placement would always be done in a fresh air stream

and with the air flowing past the placement point. When placement is completed in a given storage room, the room would be temporarily sealed and the placement ventilation airflow would be directed into the next room.

When an entire panel has been filled, the branch corridor would be bulkheaded and sealed between the just completed and the next-to-be-placed panels. This is done to isolate the panel where placement is taking place from the already filled panels.

The layout of the subterranean ventilation system would provide for separation of the potentially contaminated exhaust air of the waste placement operations from the mining operations exhaust air. As described earlier, the mining exhaust air would be collected through one of the main corridors. Placement operation exhaust air would be collected through the completely separate system of perimeter ventilation drifts. The two exhaust airflows would be brought to the surface in separate compartments of the divided Ventilation Exhaust Shaft. The air from the placement operation would be continuously treated for contamination while the backfill and mining air would be treated only when contamination is detected. The 26 ft. diameter shaft would be constructed of reinforced concrete with a smooth concrete lining, suitable for decontamination in case that ever becomes necessary. Precautions are required during construction to ensure that the shaft is free of cracks through which groundwater could seep into the shaft.

6.1.5 Exhaust Ventilation Building

The Ventilation Exhaust Shaft would terminate in the plenum chamber of the Exhaust Ventilation Building. This building, the final component in the mine ventilation system, would house the mine exhaust fans and the central filtering station. A schematic flow diagram of the exhaust air filtering system is shown on Dwg. 13.

Exhaust air from the placement compartment of the Exhaust Ventilation Shaft would always be filtered by prefilters (30% and 90% NBS efficiency) and two sets of high efficiency particulate air (HEPA) filters arranged in series. The fan-filter arrangement would handle 250,000 cfm; a duplicate fan-filter train would serve as back-up unit to ensure continuity of placement exhaust when malfunction, maintenance or filter change necessitates shut-down of the first unit. Motorized isolating dampers would be provided before and after the filter trains and in the discharge of the exhaust fans. The filtered air would then be discharged through the 100 ft. high exhaust stack that is continuously monitored to detect any radioactivity in the air stream.

Under normal operating conditions, exhaust air from the mining operations would not pass through HEPA filters. Instead, it would be drawn through a set of (normally open) dampers and 30% NBS efficiency filters, by three 600,000 cfm nominal capacity centrifugal fans serving the mining operations only, and discharged directly to the atmosphere through a stack. The three fans would be connected in parallel. Normally two of the three mining operations exhaust fans would be in operation while the third may be serviced or used as a standby. Alternate electrical power would be provided to operate any one of the three fans in the event the normal power fails.

Monitors would be located in the mining air compartment of the Ventilation Exhaust Shaft to indicate the presence of any radioactive contaminants. Under normal conditions there would be no radioactive particulates in the mining exhaust and only a minimal amount in the canister placement exhaust. In the event of an accident involving a canister leak or some other release of radioactive particles from a canister, only the placement exhaust air would become contaminated since the two air flows are separated. Although it is highly unlikely that the mining exhaust air would also exhibit the presence of radioactive elements, the capability would be provided to filter this air also. In such an event, the dampers which are normally open would close and those which are

normally closed would open. The mining exhaust air would thereby enter the same plenum chamber to which the placement compartment of the upcast shaft is connected. From this chamber four additional filter-fan trains, identical to the two units serving the placement exhaust, would draw the mine exhaust air through 30% and 90% MBS efficiency prefilters and two sets of HEPA filters before discharge to the atmosphere through the exhaust stack. Since these additional filter-fan trains would operate in case of emergency only, under normal circumstances they can serve as additional back-up units for the placement exhaust filtering system.

Differential pressure gauges would be installed on each side of each filter bank and will indicate when filter replacement is necessary. Each fan would have a nominal capacity of 250,000 cfm, and sufficient static pressure head to overcome friction losses in the mine, shaft, and stack, plus a reasonable buildup of filter resistance. Connections would be provided for in-place DOP testing of individual HEPA filter banks. Special quick-closing blast dampers would be provided in the fan discharge to the stack to protect the upstream HEPA filters from tornado damage. These dampers would be designed to withstand a 3 psi differential pressure (in the closed position) that may be imposed by a tornado.

6.1.6 Air Velocities in Subterranean Ventilation Airways

Air velocities in the ventilation airways are a function of the air flow and the size of the airway. Air flow is determined by the ventilation requirements for the mining and placement operations. In regard to the size of the airways, large airways would reduce pressure and power requirements and hence operating costs but would be expensive from the standpoint of investment or capital cost.

For the ventilation airflows required, the airway sizes selected in this preconceptual study resulted in the typical air velocities given in Table 6-3.

6.1.7 Ventilation Systems Controls

Ventilation air from the mine would be exhausted through the mining and placement exhaust fans located in the Exhaust Ventilation Building, and the underground areas would be maintained at a negative pressure. To achieve the desired distribution of the supply air and assure confinement of mine air within the mine, a system of manually and automatically activated dampers and controls would be incorporated into the ventilation system. Supply fan inlet vane controls and dampers in the supply air distribution system would operate in conjunction with dampers and regulators located in the exhaust air stream to control the air flow and pressure in the high-level and low-level waste storage areas. These fan and damper controls associated with the supply and exhaust systems would provide assurance that all exhaust air that may have come in contact with waste storage areas would be filtered under controlled conditions prior to discharge to the atmosphere.

6.1.8 Ventilation of Subterranean Waste Receiving Stations

The Canistered Waste Receiving Stations at the base of the Canistered Waste Shaft must be ventilated to ensure confinement of any radioactive contamination as well as to provide for a safe and comfortable working environment.

The subterranean waste receiving stations would be provided with separate supply and exhaust systems. Ventilation supply air would be drawn from the mine ventilation air at the base of the Ventilation Supply Shaft by a supply fan and ducted to the Observation and Control Rooms, Waste Receiving and Transporter Loading Areas. The ventilation flow rates would provide for six air changes per hour in the Observation and Control Rooms and a minimum of two air changes per hour in the Waste Receiving and Transporter Loading Areas.

Exhaust air from the subterranean waste receiving stations would be filtered through 30% and 90% NBS efficiency prefilters and one set of HEPA filters by dual fan/filter units. Filtered air would be ducted to the Ventilation Exhaust Shaft and discharged into the placement exhaust compartment of the shaft.

All spaces of the subterranean waste receiving stations would be maintained under negative pressure relative to the mine atmosphere. Upon loss of normal power the supply fans would automatically shut down and the exhaust fans would automatically operate at half speed.

6.1.9 Ventilation During Retrieval

It is assumed that all other mining and placement operations would halt if retrieval of the emplaced nuclear waste would be required. The mine ventilating system would be used first to cool down the waste storage rooms where the retrieval is to take place and then to provide ventilation during the retrieval operations.

After the temporary seal is removed at the branch corridor end of a storage room, the heat built up in the room would be removed by directing approximately 250,000 cfm supply air along the M&M corridor to the opened-up room and exhausting it through the room via the placement exhaust perimeter ventilation drift system. After the room is sufficiently cooled, the retrieval operation would be done with a lesser rate of ventilation, but sufficiently large to provide 100 fpm air velocity through the storage room. Retrieval would begin at the corridor end of the room, progressing toward the periphery ventilation drift. This way, the retrieval would always be done in the fresh air stream, and air flowing over the still emplaced canisters would be flowing away from the working points.

All exhaust air from the retrieval operations would be collected through the perimeter ventilation airway system and brought to the central filter room via the placement exhaust compartment of the Ventilation Exhaust Shaft. Filtration of the retrieval operation exhaust air would be the same as that described for the placement exhaust air filtration in Section 6.1.5. If the retrieval operation is initiated in more than one storage room at the same time, additional fan-filter trains (installed originally for filtering the mining air in emergency) can be started up to handle the

increased volume of exhaust air. The filtered air would be discharged to the atmosphere through the 100 ft. high exhaust stack.

6.2 Heating, Ventilating and Air-Conditioning of Surface Structures

6.2.1 Introduction

Heating, ventilating and air-conditioning systems would be required to provide proper working environment for personnel and equipment, and to effectively confine any airborne contamination within the facilities.

6.2.1.1 Design Conditions

Design conditions for environmental control would be based on data published in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbook of Fundamentals, latest edition. Summer and winter outside air design conditions would depend on the geographic location of the repository. Summer inside design conditions would be 78°F dry bulb (db) with 50% relative humidity in air-conditioned spaces, unless otherwise required for special equipment environment. In spaces that are not air-conditioned, temperatures would be limited to 105°F. Winter inside design conditions would be 70°F with no humidity control in air-conditioned spaces and 50°F in equipment rooms and non-occupied spaces.

6.2.1.2 Air Distribution and Design Requirements

Three major zones of air distribution have been assumed in surface structures where nuclear waste material is being handled,:

- o Zone I - Primary Confinement Zone: areas of high potential contamination;
- o Zone II -- Secondary Confinement Zone: areas of low potential contamination;
- o Zone III - Unrestricted Zone: areas of no potential contamination under normal operating conditions.

Each confinement zone would be provided with supply and exhaust systems. Supply and exhaust control dampers would provide for successively greater negative pressures between areas of successively higher contamination potential. Recirculation of air from a lower potential contamination zone to a higher potential contamination zone would be permitted if filtered through high efficiency particulate air (HEPA) filters.

Supply systems for Zone I areas would be provided with two sets of HEPA filters, DOP testable in place.

Supply systems for Zone II areas would be provided with one set of HEPA filters, DOP testable in place.

Supply systems for Zone III areas would be provided with 30% NBS and 90% NBS efficiency filters arranged in series.

Exhaust systems for Zones I and II would be:

- o Provided with at least two sets of HEPA filters, separately DOP testable in place;
- o Provided with 100% back-up (standby) systems;
- o Connected to the emergency electric power system.

Exhaust systems serving Zone III areas would have at least one set of HEPA filters, but no back-up system or emergency power supply is required.

Upon loss of normal power, the outside air supply fans would automatically shut down, and the confinement zone exhaust fans would automatically operate at half speed.

All supply and exhaust systems where HEPA filters are required would also be provided with 30% NBS and 90% NBS efficiency filters, arranged in series upstream of the HEPA filters. Conventional low-velocity duct systems design would be used for all supply and exhaust systems.

6.2.1.3 Heating and Cooling

Heating would be provided by hot water coils in the air-conditioning units, fan-coil units, unit heaters and cabinet heaters. Hot water would be circulated from the steam-to-water converters located in the mechanical equipment room of each building. Steam generated in the central boiler plant for the whole facility would

be distributed through underground utility tunnels. Electrical cabinet heaters would be used in small and remotely located surface buildings.

In general, cooling would be provided by the chilled water supplied to the air-conditioning units and fan-coil units from the central refrigeration plant. In small and remotely located buildings (such as the railway guardhouse) unitary room air conditioners would be utilized.

6.2.2 Canistered Waste Receiving Building HVAC Systems

Outside air for ventilation of the Canistered Waste Receiving Building would be provided by air-conditioning units located in the Mechanical Equipment Room. Confinement chambers would be provided to the restricted zones to maintain the confinement integrity of the nuclear waste handling areas. The air supply to, and the pressure within individual rooms would be regulated by static pressure regulators and automatic pressure and volume control dampers. Confinement zone classification of various rooms and specific ventilation design requirements are shown in Table 6-4.

6.2.2.1 Description of Heating, Ventilating and Air-Conditioning Systems

The schematic air flow diagram for the Canistered Waste Receiving Building is shown on Dwg. 6. The outside air would be drawn through prefilters (30% and 90% NBS efficiency) and HEPA filters, conditioned and then supplied to the operating galleries and cask unloading areas. A back-up supply fan/air-conditioning unit would be provided for operational reliability. A room thermostat from one of the operating galleries would modulate control valves of the heating or cooling coils in these air-conditioning units. To reduce the heating/cooling load on the outside air supply units, supplementary ventilation and cooling would be provided in each of the Cask Unloading Rooms by filter/air-conditioning units. These approximately 15 ton capacity units would draw air from the operating galleries, filter it through prefilters and

two HEPA filters arranged in series, condition it and discharge into the Cask Unloading space. Room thermostats in each Cask Unloading Room would modulate the cooling coil control valve of the respective supplementary unit.

Part of the return air from the Cask Unloading Rooms would be supplied to the primary confinement zone area (Transfer Galleries, Transfer Cells and the Canister Storage and Feed Room), after it is filtered through prefilters and two sets of HEPA filters. Surplus return air not required for Zone I ventilation would be exhausted to the atmosphere after filtering as described below.

In the Transfer Cells and Canister Storage & Feed Room, fan-coil units will be provided (with back-up units, rated at 100% of required capacity) to prevent excessive room temperatures due to heat emitted by process equipment, lighting and the nuclear waste canisters.

Exhaust air from the primary confinement zone areas and excess return air from the secondary confinement zones would be processed through dual HEPA filter units with one operating and one on standby. The filtered air would be drawn through underground ducts to the dual exhaust fans located in the exhaust vent building, and discharged into the mine exhaust stack. The combined air flow rates from the primary and secondary confinement zones of the Canistered Waste Receiving Building are estimated to be 91,000 cfm for all three fuel cycles.

Exhaust from unrestricted support facility rooms and from the mechanical equipment room would be filtered through prefilters and two sets of HEPA filters before being discharged to the atmosphere from the exhaust fan located in the mechanical room of the Canistered Waste Building.

Mechanical Equipment Room and the Exhaust Filter Room would be provided with a heating and ventilating unit. Outside air would be filtered as required for Zone II supply systems and discharged into the Mechanical Equipment Room. Exhaust air from this space would be supplied to the restricted (Zone II) Exhaust Filter Room. The exhaust system serving the Filter Room will have filters as required for Zone II systems, but no standby unit or emergency power connection would be provided.

Electrical Equipment Room would be provided with a separate ventilating unit for summer ventilation. During the winter, room thermostat controlled unit heaters would maintain the minimum design temperature in the room.

Hoist Machine Room would be provided with a separate air-conditioning unit using a combination of recirculated air and the minimum required rate of outside air to provide the desired room pressure, ventilation and summer-winter design temperature. A room thermostat will modulate the cooling and heating coil control valves in the air-conditioning unit. Air would be exhausted to the atmosphere after filtration through prefilters (30% and 90% NBS efficiency) and two sets of HEPA filters.

The Battery Room would be ventilated by a continuously running exhaust fan to ensure a safe low level of hydrogen concentration in the room. The exhaust fan would have a spark-proof wheel and explosion-proof motor construction.

Supply air for the Mechanical Equipment Room and the Exhaust Filter Room would be provided by a heating and ventilating unit. Outside air drawn by the fan would be filtered by 30% and 90% NBS efficiency filters. A duct thermostat downstream of the supply fan would modulate the heating coil control valve in the heating operation mode. Supplementary heating would be provided for the Mechanical Equipment Room by room thermostat-controlled unit heaters to maintain a minimum 50°F in the room. Exhaust air from the Mechanical Equipment Room would be handled by the fan/filter unit serving the Zone III areas. Exhaust air from the Exhaust Filter Room would be filtered through the filter/fan unit serving the secondary confinement zone rooms.

The Electrical Equipment Room would be provided with a separate ventilating unit for summer ventilation. During the winter, unit heaters would maintain the minimum winter design room temperature, controlled by room thermostats.

The Hoist House would be provided with a separate air-conditioning unit using a combination of recirculated air and the minimum required rate of outside air to provide the desired space

pressure, ventilation and summer-winter design temperature. A room thermostat would modulate the cooling and heating coil control valves in the air-conditioning unit. Air would be exhausted to the atmosphere after filtration through prefilters (30% and 90% NBS efficiency) and two sets of HEPA filters.

6.2.3 Low-Level Waste Facility Receiving HVAC Systems

The ventilation air flow diagram for the Low-Level Waste Receiving Building for all fuel cycles is shown on Dwg. 9. Outside air for the ventilation of the Low-Level Waste Receiving Building would be provided by air-conditioning units located in the Mechanical Equipment Room. Independent supply and exhaust systems would serve the non-restricted and the secondary confinement zone areas. Confinement chambers would be provided to the restricted zones to maintain the confinement integrity of the nuclear waste handling areas. The air supply to and the pressure within individual rooms would be regulated by static pressure regulators and automatic pressure and volume control dampers. Confinement zone classification of various rooms and specific ventilation design requirements are shown in Table 6-5.

Supply air for the Zone II rooms would flow through prefilters (30% and 90% NBS efficiency) and one set of HEPA filters, heating and cooling coils, and a backflow preventer before being distributed to the rooms. Exhaust air from the confinement zones would be processed through prefilters and two HEPA filters in series, and then discharged to the atmosphere. A duplicate filter bank and exhaust fan installation would be provided for operational reliability, and the exhaust fans would be linked to the alternate power distribution system. Upon loss of normal power, the confinement zone ventilation supply system would automatically shut down and the exhaust fan would automatically operate at half speed. Exhaust air flow rates from the secondary confinement zones are estimated to be 8200 cfm for Cycles II and III repository designs, and 12,300 cfm for Cycle I repository design.

Outside air for the non-restricted zone rooms would be filtered through a prefilter (30% NBS) and a main filter (90% NBS) and heated

or cooled before distribution. The nonrestricted zone exhaust system would not have auxiliary back-up capabilities, nor would it be linked to the emergency power network.

6.2.4 Liquid Radwaste Treatment Facility

The Liquid Radwaste Treatment Building would be provided with a separate, independent ventilation system. System capacity would provide a minimum of 10 air changes per hour. Potentially contaminated rooms would be maintained under negative pressure relative to the atmosphere, and an overpressure condition would automatically close all vents from a room.

Exhaust air filtering would include an 85% NBS efficiency prefilter and two HEPA filter banks in series. The control room for the liquid radwaste treatment operations would be provided with an independent climate control system.

6.2.5 Other Surface Structures

The Administration Building and the Mine Operations Building would be provided with year-round central air-conditioning. The system would be designed to recirculate air from the office spaces, drawing only the minimum required outside air. During heating seasons, supplementary heat would be provided by fin tube convectors, cabinet heaters, and unit heaters as determined by the function of spaces served.

Central Site Control and Switchgear Building: General office spaces would be air-conditioned by a central system with the same design features as described above for the Administration Building system. The Control Room and related control equipment spaces would be provided with packaged computer room air-conditioning units to control space temperature and humidity as required for the equipment environment and human comfort. Emergency units would be provided in the Control Room, and both the normally operating units and the back-up units would be connected to the emergency power network. The switchgear area would be ventilated in the summer and heated in the winter to maintain design space conditions.

Supply Ventilation Building: The electrical switchgear room of this building would be provided with ventilation supply air fans and relief vent opening to limit the maximum summer space temperature to 105°F. Other ancillary spaces in the building would be provided with a heating and ventilating unit. For supplementary heating, cabinet heaters and unit heaters would be used.

Exhaust Ventilation Building: Separate ventilating systems would be provided for the subgrade mechanical fan rooms and Computer Room and for the at-grade Filter Change area. Supply and exhaust control dampers would maintain negative pressure relative to atmosphere. Exhaust air would be filtered as required for secondary confinement zone exhaust and discharged to atmosphere through the mine exhaust stack. Unit heaters would be provided as required to maintain indoor temperature at 50°F.

Cafeteria Building: The dining area would be served by an air-conditioning unit supplying 100% outside air. Return air from the dining area would be filtered and supplied to the kitchen area by a transfer fan. To meet the total kitchen area ventilation requirements, a separate heating and ventilating would also serve the kitchen areas. The exhaust fan and ductwork from the kitchen areas would be designed to meet requirements of the application. Heating would be provided by fin tube convectors, unit heaters and cabinet heaters as required.

The Laundry Building would be provided with a heating and ventilating unit; exhaust fan and stainless steel or aluminum ductwork would be provided to discharge the air to the atmosphere.

The Clinic Building would be air-conditioned by a central unit; separate exhaust systems would be provided for general area exhaust and for the clinic rooms.

Locker rooms of the Men and Material Building would be ventilated by a heating and ventilating unit. Briefing rooms and offices would be air conditioned by self-contained air-conditioning units. Heating would be provided by cabinet and unit heaters.

The Warehouse and Maintenance Building would be provided with a supply fan ventilation unit and relief air openings. Winter design space temperature would be maintained by steam unit heaters controlled by individual space thermostats.

The Fire House would be ventilated in the summer to keep the indoor temperature below design limits. Unit heaters would be provided for heating in the winter to maintain 50°F indoor temperature. The Fire Warden's office would be air-conditioned by a self-contained air-conditioning unit.

Guardhouses would be provided with self-contained air-conditioning units; heating would be provided by electric cabinet heaters.

6.3 Ventilation of 25-Year Retrievable Repositories

6.3.1 25-Year Retrievability without Heat Removal

In this alternative repository design, 25-year retrievability is achieved by reducing the allowable local thermal loading as compared to the 5-year retrievable repository designs. (See Section 5.11.)

Mine ventilation criteria and the method of ventilating the mining and placement operations is the same as for the 5-year retrievable repository, described in Section 6.1. The conceptual layout for the subterranean ventilation system is the same as shown on Dwg. D19. The total ventilation airflow, however, shown in Table 6-2, is less than that required for the 5-year retrievable repository because of the fewer number of drilling crews operating simultaneously and because no backfill ventilation is considered.

Provisions for filtering the mining and placement exhaust air would be the same as described in Section 6.1.5 for 5-year retrievable repository designs.

6.3.2 25-Year Retrievability with Heat Removal

In this alternative repository design, 25-year retrievability is achieved in the BWR rooms by using a reduced local areal thermal loading and, in the PWR storage rooms, by also removing portions of the waste-generated heat through continuous ventilation. (See Section 5.11.)

Mine ventilation criteria and the method of supplying fresh air to the mining and placement operation work areas are the same

as described in Section 6.1 for the 5-year retrievable repository. The conceptual layout of the subterranean ventilation system is shown on Dwg. E21. The layout of the ventilation system would provide for separation of the potentially contaminated exhaust air of placement and heat removal from the exhaust air of mining operations. The mining exhaust air would be brought to the surface through a separate 22 ft. diameter concrete-lined Ventilation Exhaust Shaft.

Placement ventilation and heat removal exhaust air would be collected through the completely separate system of perimeter ventilation airways and brought to the surface through a 24 ft. diameter Ventilation Exhaust Shaft. The shaft would have a smooth surfaced concrete lining, suitable for decontamination if that ever becomes necessary.

Ventilation airflow requirements for mining, placement and heat removal are shown in Table 6-3. Total ventilation requirements for placement operations are estimated to be 250,000 cfm, the same as for 5-year retrievable repositories. (See Section 6.1.4.) Heat removal from each PWR room would start when the placement operation is completed and would be continuous from then on during the retrievability period. To limit the effective local areal thermal loading to the allowable maximum value (See Section 5.11), it is estimated that 9,000 cfm per 3,500 ft. long room would be required, assuming that the temperature of the air leaving the room is a maximum of 60⁰ F above the temperature of the air entering the room. In the last year of placement operations, when nearly all PWR rooms would already be ventilated for heat removal, approximately 1,250,000 cfm would be required for heat removal ventilation. The sum of this flow rate plus the 250,000 cfm required for placement ventilation is shown in Table 6-2.

Maximum ventilation air demand would occur during the last year of mining operations at peak yearly production estimated to occur in the year 2000. Corresponding total exhaust air from mining, placement, and heat removal is about 2,200,000 cfm. Eight supply fans (with two additional fans serving as standby) would

provide the required ventilation supply air flow through the 27 ft. diameter Ventilation Supply Shaft. The conceptual layout of the Supply Ventilation Building, housing the supply fans, is shown on Dwg. E16. The treatment of the supply air will be the same as described in Section 6.1.2.

Exhaust air from the placement and heat removal would always be filtered by prefilters (30% and 90% NBS efficiency) and two sets of HEPA filters arranged in series. A total of eight fan-filter trains would be provided (including two back-up units) in the Exhaust Ventilation Building #1, arranged as shown in Dwg. E15. The filtered air is discharged to the atmosphere through the 100 ft. high exhaust stack.

Exhaust Ventilation Building #2 would contain fans and filters for exhausting the mining air. The conceptual flow diagram of the exhaust system is shown on Dwg. E15. Under normal circumstances two nominal 550,000 cfm capacity fans would exhaust the mining operation air, with a third fan of the same capacity serving as a standby. Additionally, four nominal 275,000 cfm capacity fan-filter trains would be provided, to afford the capability for filtration of all mining air through HEPA filters under emergency conditions. Detailed description of normal and emergency operating conditions of the underground exhaust systems is given in Section 6.1.5.

SURFACE FACILITIES

FIG. I

WASTE ISOLATION FACILITY

FIG. 2

CANISTERED WASTE BLDG. CUTAWAY PERSPECTIVE

FIG. 3

FIG. 4

WASTE RECEIVING OPERATIONS CUTAWAY PERSPECTIVE

Salt

CYCLE I

HLW: Extraction Ratio = 23%

ILW & CW: Extraction Ratio = 46%

CYCLE II

PWR/BWR: Extraction Ratio = 25%

CYCLE III: Same as CYCLE I

EXTRACTION RATIO CHART

FIG. 5

Table 1-1
CANISTER RECEIPT CRITERIA RECOMMENDATIONS

Contents	Canister		Overpack		Age (Years)	Maximum Radiation Level (Rem/Hr)			
	Outside Diameter (inches)	Overall Length (feet)	Outside Diameter (inches)	Overall Length (feet)		At Surface		10' from Ctr. Line	
						gamma dose rate	neutron dose rate	gamma dose rate	neutron dose rate
HLW in Glass	12-3/4	10	14	11	10	2.0x10 ⁵	1.0x10 ²	1.0x10 ⁴	1.0x10 ¹
HLW in Calcine	8-5/8	10	10-3/4	11	10	5.0x10 ⁵	1.0x10 ²	5.0x10 ⁴	1.0x10 ¹
IL-TRU	12-3/4	10	14	11	5	1.0x10 ²	1.0x10 ⁻¹	1.0x10 ¹	5.0x10 ⁻³
Cladding	12-3/4	10	14	11	5	1.0x10 ³	1.0x10 ⁻¹	1.0x10 ¹	5.0x10 ⁻³
PWR	14	16	16	16-1/2	10	7.0x10 ⁴	1.0x10 ¹	3.5x10 ³	5.8x10 ⁻¹
BWR	10-3/4	16	12-3/4	16-1/2	10	5.0x10 ⁴	1.0x10 ¹	2.5x10 ³	5.8x10 ⁻¹

ADDITIONAL RECEIPT CRITERIA
(For All Canisters)

Max. Weight (incl. overpack) = 3000 lbs.

Max. outer surface contamination
with transferable radioisotopes:

beta-gamma radiation emitting nuclides: $10,000 \text{ dis/min/dm}^2$ (disintegration/minute/100 cm²)
alpha emitting nuclides: 300 dis/min/dm^2

Source: TM-36/2, Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies.

Table 1-2

Personnel Assignment Schedule
Salt - Cycle I

Year	Waste Storage Operation	Mining Operation *	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	55	-	-	-	119
1982	77	135	-	-	-	212
1983	85	299	-	-	-	384
1984	93	304	56	23	-	556
1985	657	391	114	30	-	1192
1986	677	474	138	30	-	1319
1987	696	474	138	30	-	1338
1988	731	474	138	30	-	1373
1989	787	474	138	-	-	1399
1990	809	474	138	-	30	1451
1991	845	474	138	-	30	1487
1992	845	474	138	-	30	1487
1993	845	474	138	-	30	1487
1994	935	453	132	-	29	1549
1995	1018	474	138	-	30	1660
1996	1048	453	132	-	30	1663
1997	1156	453	132	-	30	1771
1998	1156	474	138	-	30	1798
1999	1174	474	138	-	30	1816
2000	1299	474	138	-	30	1941
2001	1299	453	132	-	29	1913
2002	1379	268	78	-	231	1956
2003	1455	-	78	-	199	1732
2004	1467	-	78	-	199	1744
2005	1561	-	-	-	199	1760
2006**	1561	-	-	-	165	1726
2007	220	-	-	-	165	385
2008	146	-	-	-	132	278
2009	110	-	-	-	99	209
2010	73	-	-	-	66	139
2011	37	-	-	-	33	70

*The mining operation is monitored by a separate Mining Production Management Group which has a staff of 138 individuals.

**Capacity of mine expired after year 2006.

Not included:

1. Overall management and engineering
2. Contingencies
3. General Contractor's personnel for initial development (1980-1984)

Note: Above figures represent the average daily manning requirements during the indicated year based on 3 shift operation including surface and subsurface personnel for each category.

Table 1-3
Personnel Assignment Schedule
Salt - Cycle II

Year	Waste Storage Operation	Mining Operation*	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	62	-	-	-	126
1982	77	153	-	-	-	230
1983	85	341	-	-	-	426
1984	93	439	50	18	-	600
1985	424	215	106	11	-	756
1986	439	215	106	11	-	771
1987	451	215	106	11	-	783
1988	468	215	106	12	-	801
1989	486	215	106	-	-	807
1990	496	215	106	-	-	817
1991	513	215	106	-	18	852
1992	513	323	158	-	27	1021
1993	513	323	158	-	27	1021
1994	545	323	158	-	27	1053
1995	576	323	158	-	27	1084
1996	586	323	158	-	27	1094
1997	627	323	158	-	27	1135
1998	627	323	158	-	27	1135
1999	633	323	158	-	27	1141
2000	674	323	158	-	27	1182
2001	674	430	211	-	36	1351
2002	700	215	106	-	18	1039
2003	725	215	106	-	18	1064
2004	729	215	106	-	18	1068
2005	763	108	53	-	9	933
2006	763	-	53	-	168	984
2007	829	-	53	-	168	1050
2008**	830	-	-	-	168	998
2009	220	-	-	-	168	388
2010	146	-	-	-	112	258
2011	110	-	-	-	84	194
2012	73	-	-	-	56	129
2013	37	-	-	-	28	65

*The mining operation is monitored by a separate Mining Production Management Group which has a staff of 138 individuals.

**Capacity of mine expired after year 2008.

Not included:

1. Overall management and engineering
2. Contingencies
3. General Contractor's personnel for initial development (1980-1984)

Note: Above figures represent the average daily manning requirements during the indicated year based on 3 shift operation including surface and subsurface personnel for each category.

Table 1-4
Personnel Assignment Schedule
Salt - Cycle III

Year	Waste Storage Operation	Mining Operation*	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	55	-	-	-	119
1982	77	135	-	-	-	212
1983	85	299	-	-	-	384
1984	93	384	56	-	-	556
1985	458	391	111	30	-	990
1986	474	474	135	30	-	1113
1987	487	474	135	30	-	1126
1988	507	474	135	30	-	1146
1989	528	474	135	-	-	1137
1990	539	474	135	-	30	1178
1991	558	474	135	-	30	1197
1992	558	474	135	-	30	1197
1993	558	474	135	-	30	1197
1994	596	453	129	-	29	1207
1995	633	474	135	-	30	1272
1996	645	453	129	-	30	1257
1997	692	453	129	-	30	1304
1998	692	474	135	-	30	1331
1999	702	474	135	-	30	1341
2000	749	474	135	-	30	1388
2001	749	453	129	-	29	1360
2002	780	-	76	-	252	1108
2003	810	-	76	-	221	1107
2004	815	-	-	-	189	1004
2005	855	-	-	-	189	1044
2006	855	-	-	-	189	1044
2007**	934	-	-	-	158	1092
2008	220	-	-	-	158	378
2009	146	-	-	-	126	272
2010	110	-	-	-	95	205
2011	73	-	-	-	63	136
2012	37	-	-	-	32	69

*The mining operation is monitored by a separate Mining Production Management Group which has a staff of 138 individuals.

**Capacity of mine expired after year 2007.

Not included:

1. Overall management and engineering
2. Contingencies
3. General Contractor's personnel for initial development (1980-1984)

Note: Above figures represent the average daily manning requirements during the indicated year based on 3 shift operation including surface and subsurface personnel for each category.

Table 3-1

Summary of Electrical Loads - Salt

	Salt - Cycle I 5 Yr. Retrievable			Salt - Cycle II 5 Yr. Retrievable			Salt - Cycle II 25 Yr. Retrievable			Salt - Cycle II 25 Yr. Ret. (HR)			Salt - Cycle III 5 Yr. Retrievable		
	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA
Admin. Bldg.	211	168	9	211	168	9	211	168	9	211	168	9	211	168	9
Clinic	136	92	20	136	92	20	136	92	20	136	92	20	136	92	20
Whse. & Veh. Maint.	88	67	3	88	67	3	88	67	3	88	67	3	88	67	3
Gd. House Psnl.	29	23	2	29	23	2	29	23	2	29	23	2	29	23	2
Gd. House RR Chk.	20	17	6	20	17	6	20	17	6	20	17	6	20	17	6
Cafeteria	177	129	5	177	129	5	177	129	5	177	129	5	177	129	5
Laundry	130	86	3	130	86	3	130	86	3	130	86	3	130	86	3
Firehouse	59	47	15	59	47	15	59	47	15	59	47	15	59	47	15
M&M Bldg.	437	290	56	437	290	56	437	290	56	437	290	56	437	290	56
Mine Oper. Bldg.	36	28	3	36	28	3	36	28	3	36	28	3	36	28	3
Oil Dpt. & Gen. Bldg.	102	81	62	102	81	62	102	81	62	102	81	62	102	81	62
Stg. Bldg.	63	51	2	63	51	2	63	51	2	63	51	2	63	51	2
Water Tower	92	65	58	92	65	58	92	65	58	92	65	58	92	65	58
Exhst. Vent. Bldg. #1	4790	3780	423	4790	3780	423	4790	3780	423	5642	4461	15	4790	3780	423
Exhst. Vent. Bldg. #2	--	--	--	--	--	--	--	--	--	3650	2881	423	--	--	--
Supply Vent. Bldg.	2242	1701	10	2242	1701	10	2242	1701	10	2900	2227	10	2242	1701	10
Boiler Plant	1120	892	228	1120	892	228	1120	892	228	1120	892	228	1120	892	228
Refrig. Bldg.	393	314	25	393	314	25	393	314	25	393	314	25	393	314	25
HLW Bldg.	1966	926	657	1966	926	657	1966	926	657	1966	926	657	1966	926	657
LL-TRU Bldg.	232	141	109	232	141	109	232	141	109	232	141	109	232	141	109
Radwaste Bldg.	169	109	10	169	109	10	169	109	10	169	109	10	169	109	10
Alarm Cmnd. Ctr.	130	107	70	130	107	70	130	107	70	130	107	70	130	107	70
Roadway Lighting	96	96	78	96	96	78	96	96	78	96	96	78	96	96	78
Security L'ting.	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
M&M Cage Hoist	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Aux. M&M Hoist	136	136	--	136	136	--	136	136	--	136	136	--	136	136	--
M&M Skip Hoist	2952	2952	--	2952	2952	--	2952	2952	--	2952	2952	--	2952	2952	--
HLW Hoist #1	429	429	--	429	429	--	429	429	--	429	429	--	429	429	--
HLW Hoist #2	429	429	--	429	429	--	429	429	--	429	429	--	429	429	--
LL-TRU Hoist	843	843	--	843	843	--	843	843	--	843	843	--	843	843	--
Undergrd. Serv., Transfer Sta., & Mine Lighting	5939	3174	307	4723	2599	252	4538	2499	240	4734	2610	253	5543	2950	285
Mining Substa. #1	6995	5246	--	5403	4052	--	6683	5012	--	6861	5146	--	6995	5246	--
Mining Substa. #2	3233	2425	--	2813	2110	--	2838	2129	--	2905	2179	--	1907	1430	--
Mining Substa. #3	4365	3274	--	3535	2651	--	4689	3517	--	6670	5003	--	4365	3274	--
TOTALS	38731	28810	2853	34673	26103	2798	36945	27848	2786	44529	33717	2814	37009	27591	2831

Table 3-1

Summary of Electrical Loads - Salt

	Salt - Cycle I 5 Yr. Retrievable			Salt - Cycle II 5 Yr. Retrievable			Salt - Cycle II 25 Yr. Retrievable			Salt - Cycle II 25 Yr. Ret. (HR)			Salt - Cycle III 5 Yr. Retrievable		
	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA	Conn. KVA	Oper. KVA	Emerg. KVA
Admin. Bldg.	211	168	9	211	168	9	211	168	9	211	168	9	211	168	9
Clinic	136	92	20	136	92	20	136	92	20	136	92	20	136	92	20
Whse. & Veh. Maint.	88	67	3	88	67	3	88	67	3	88	67	3	88	67	3
Gd. House Psnl.	29	23	2	29	23	2	29	23	2	29	23	2	29	23	2
Gd. House RR Chk.	20	17	6	20	17	6	20	17	6	20	17	6	20	17	6
Cafeteria	177	129	5	177	129	5	177	129	5	177	129	5	177	129	5
Laundry	130	86	3	130	86	3	130	86	3	130	86	3	130	86	3
Firehouse	59	47	15	59	47	15	59	47	15	59	47	15	59	47	15
M&M Bldg.	437	290	56	437	290	56	437	290	56	437	290	56	437	290	56
Mine Oper. Bldg.	36	28	3	36	28	3	36	28	3	36	28	3	36	28	3
Oil Dpt. & Gen. Bldg.	102	81	62	102	81	62	102	81	62	102	81	62	102	81	62
Stg. Bldg.	63	51	2	63	51	2	63	51	2	63	51	2	63	51	2
Water Tower	92	65	58	92	65	58	92	65	58	92	65	58	92	65	58
Exhst. Vent. Bldg. #1	4790	3780	423	4790	3780	423	4790	3780	423	5642	4461	15	4790	3780	423
Exhst. Vent. Bldg. #2	--	--	--	--	--	--	--	--	--	3650	2881	423	--	--	--
Supply Vent. Bldg.	2242	1701	10	2242	1701	10	2242	1701	10	2900	2227	10	2242	1701	10
Boiler Plant	1120	892	228	1120	892	228	1120	892	228	1120	892	228	1120	892	228
Refrig. Bldg.	393	314	25	393	314	25	393	314	25	393	314	25	393	314	25
HLW Bldg.	1966	926	657	1966	926	657	1966	926	657	1966	926	657	1966	926	657
LL-TRU Bldg.	232	141	109	232	141	109	232	141	109	232	141	109	232	141	109
Radwaste Bldg.	169	109	10	169	109	10	169	109	10	169	109	10	169	109	10
Alarm Cmd. Ctr.	130	107	70	130	107	70	130	107	70	130	107	70	130	107	70
Roadway Lighting	96	96	78	96	96	78	96	96	78	96	96	78	96	96	78
Security L'ting.	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
M&M Cage Hoist	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Aux. M&M Hoist	136	136	--	136	136	--	136	136	--	136	136	--	136	136	--
M&M Skip Hoist	2952	2952	--	2952	2952	--	2952	2952	--	2952	2952	--	2952	2952	--
HLW Hoist #1	429	429	--	429	429	--	429	429	--	429	429	--	429	429	--
HLW Hoist #2	429	429	--	429	429	--	429	429	--	429	429	--	429	429	--
LL-TRU Hoist	843	843	--	843	843	--	843	843	--	843	843	--	843	843	--
Undergrd. Serv., Transfer Sta., & Mine Lighting	5939	3174	307	4723	2599	252	4538	2499	240	4734	2610	253	5543	2950	285
Mining Substa. #1	6995	5246	--	5403	4052	--	6683	5012	--	6861	5146	--	6995	5246	--
Mining Substa. #2	3233	2425	--	2813	2110	--	2838	2129	--	2905	2179	--	1907	1430	--
Mining Substa. #3	4365	3274	--	3535	2651	--	4689	3517	--	6670	5003	--	4365	3274	--
TOTALS	38731	28810	2853	34673	26103	2798	36945	27848	2786	44529	33717	2814	37009	27591	2831

TABLE 4-1

SALTSHAFT DIAMETERS (Feet)

<u>DESIGNATION</u>	<u>5-Year Retrievable</u>			<u>25-Year Retrievable</u>	
	<u>CYCLE I</u>	<u>CYCLE II</u>	<u>CYCLE III</u>	<u>CYCLE II</u>	<u>HR (a)</u> <u>CYCLE II</u>
MEN & MATERIAL SHAFT	27	27	27	27	27
LOW-LEVEL WASTE SHAFT	10	10	10	10	10
CANISTERED WASTE SHAFT	14	14	14	14	14
VENTILATION SUPPLY SHAFT	26	26	26	22	27 (b)
VENTILATION EXHAUST SHAFT	26	26	26	22	22/24 ^(c)
SERVICE SHAFT	--	--	--	--	17

a) Special case where heat is mechanically removed from PWR rooms.

b) A portion of the Ventilation Supply Air is supplied via the M&M shaft.

c) 22' Diameter for mining operations.

24' Diameter for placement operations and heat removal.

Table 4-2

Basic Shaft Information for Salt

<u>Shaft Function</u>	<u>Diameter (Inside)</u>	<u>Depth</u>	<u>Excavation Method</u>
Men and Material	27 ft.	1900 ft.	Conventional
Ventilation Supply	26 ft.	1850 ft.	Conventional
Ventilation Exhaust	26 ft.	1850 ft.	Conventional
Canistered Waste	14 ft.	1900 ft.	Conventional
Low-Level Waste	10 ft.	2000 ft.	Bored

Table 4-3

Hydrostatic Shaft Liner Specifications

Shaft Name Shaft Diameter	M&M 27'	Vent. Supply and Exhaust 26'	Can. Waste 14'	LLW* 10'
<u>No. 1 Aquifer</u>				
Steel Liner Thickness	-	-	-	3/8" PL
Liner Yield Strength	-	-	-	50,000
Concrete Thickness	12"	12"	12"	12"
Concrete Strength	3,500	3,500	3,500	3,500
<u>No. 2 Aquifer</u>				
Steel Liner Thickness	-	-	-	3/8" PL
Liner Yield Strength	-	-	-	50,000
Concrete Thickness	12"	12"	12"	12"
Concrete Strength	3,500	3,500	3,500	3,500
<u>No. 3 Aquifer</u>				
Steel Liner Thickness	1" PL	1" PL	1/2" PL	3/8" PL
Liner Yield Strength	50,000	50,000	50,000	50,000
Concrete Thickness	24"	24"	12"	12"
Concrete Strength	3,500	3,500	3,500	3,500
<u>No. 4 Aquifer</u>				
Steel Liner Thickness	-	-	-	3/8" PL
Liner Yield Strength	-	-	-	50,000
Concrete Thickness	12"	12"	12"	12"
Concrete Strength	3,500	3,500	3,500	4,000
<u>No. 5 Aquifer</u>				
Steel Liner Thickness	1" PL	1" PL	1/2" PL	5/8" PL
Liner Yield Strength	50,000	50,000	50,000	50,000
Concrete Thickness	24"	24"	12"	12"
Concrete Strength	5,400	5,000	5,000	3,500
<u>No. 6 Aquifer</u>				
Steel Liner Thickness	1 1/2" PL	1 1/2" PL	3/4" PL	1" PL
Liner Yield Strength	50,000	50,000	50,000	50,000
Concrete Thickness	30"	30"	18"	12"
Concrete Strength	6,000	6,000	6,000	6,000
<u>No. 7 Aquifer</u>				
Steel Liner Thickness	1 1/2" PL	1 1/2" PL	3/4" PL	1 1/4" PL
Liner Yield Strength	50,000	50,000	50,000	50,000
Concrete Thickness	30"	30"	18"	12"
Concrete Strength	6,000	6,000	6,000	6,000

* Single Steel Plate Liner

Table 5-1

LOCAL AREAL THERMAL LOADINGS

<u>Medium</u>	<u>Cycle</u>	<u>Waste Type</u>	(a)	(b)	(c)
			<u>Average KW/can</u>	<u>Allow. areal therm. ldg.</u>	<u>Actual areal therm. ldg.</u>
Salt	I	HLW(glass)	2.8	150	148
	II	PWR	0.55	150	125
		BWR	0.18	150	41 ^(d)
	III	HLW + Pu (glass)	2.6	150	148
	II (25-yr. N.H.R.)	PWR	0.55	36	36
		BWR	0.18	36	36
	II (25-Yr. H.R.)	PWR	0.55	60	60
		BWR	0.18	36	36

a) Memo No. SAI-30, dated August 30, 1977.

b) Memo No. SAI-30, dated August 30, 1977.

c) Actual areal heat load is calculated by dividing the heat of the total number of canisters per room by the area of the room plus one interior pillar.

d) See Sect. 5.1, "Mine Layout" for explanation of constraint on thermal loading.

Table 5-2
SALT REPOSITORY SUMMARY

<u>Cycle (Date Filled)</u>	<u>Waste Type</u>	<u>Capacity (No. Con- tainers)</u>	<u>Room Length (feet)</u>	<u>Room Opening W x H (ft.)</u>	<u>Approx.⁽¹⁾ Area (Acres)</u>	<u>No. Rooms</u>	<u>Waste Units/ Room</u>	<u>Total No. Panels</u>	<u>Rooms per Panel</u>	<u>No.⁽²⁾ Rows</u>	<u>Longitud. Spacing ea. Row</u>	<u>Storage Configuration</u>
I-Total Recycle (2006)	HLW	41,340	560	18 x 20	1018	780	53	1 19	20 40	1	10 ft.	Canisters in holes
	IL-TRU	274,485	1575			4	1265					
	CW	57,055	3150	36 x 20	649	108	2580	36	4	5	6 ft.	Canisters in holes
			1850		135	32	1495					
	LL-TRU	571,200	2000	36 x 20	108	28	20,400	7	4	-	-	Palletized drums
II-Spent Unrepro- cessed Fuel (2008)	PWR	134,648	3500	18 x 22	700	104	1150	26	4	2	6 ft.	Canisters in holes
			1300			36	418	9				
	BWR	200,016	3500	18 x 22	1035	144	1150	36	4	2	6 ft.	Canisters in holes
			2910			36	956	9				
	LLW	60,192	1374	18 x 22	97	12	5016	3	4	-	-	Palletized drums
III- U only Cycle (2007)	HLW	44,460	560	18 x 20	1018	780	57	1 19	20 40	1	9 ft.	Canisters in holes
	IL-TRU	246,780	1575			4	1190					
	CW	60,260	3150	36 x 20	649	108	2390	36	4	5	6.5 ft.	Canisters in holes
			1850		135	32	1380					
	LL-TRU	81,600	1000	36 x 20	14	8	10,200	2	4	-	-	Palletized drums

1) Approximate area is gross acreage associated with each storage section including main corridors, exhaust corridors and buttress pillars; it is not the net area used to calculate areal heat loads.

2) Refers to rows of canisters in each room.

Table 5-3

HIGH-LEVEL WASTE RECEIVING RATES^{a,e} - SALT (Cycles I and III)

Year	<u>Glass Waste Canisters^b</u>		<u>Calcine Waste Canisters^c</u>	
	<u>Annual</u>	<u>Accumulated</u>	<u>Annual</u>	<u>Accumulated</u>
1985 ^d	92	92	103	103
1986	368	460	414	517
1987	489	949	550	1067
1988	554	1503	623	1690
1989	626	2129	704	2394
1990	676	2805	760	3154
1991	911	3716	1024	4178
1992	1033	4749	1161	5339
1993	1158	5907	1302	6641
1994	1324	7231	1488	8129
1995	1560	8791	1753	9882
1996	1646	10437	1850	11732
1997	1872	12309	2104	13836
1998	2092	14401	2351	16187
1999	2329	16730	2618	18805
2000	2573	19303	2892	21697
2001	2804	22107	3152	24849
2002	3051	25158	3429	28278
2003	3299	28457	3708	31986
2004	3554	32011	3995	35981
2005	3809	35820	4281	40262
2006	4062	39882	4566	44828
2007	4300	44182	4833	49661
2008	4525	48707	5086	54747
2009	4744	53451	5332	60079
2010	4956	58407	5570	65649

^aBased on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity by the year 2000 (10 year delay prior to burial).

^bAssuming waste density of 3.0 ft³/MTU and canister volume of 6.28 ft³ (0.178m³).

^cAssuming waste density of 1.5 ft³/MTU and canister volume of 2.79 ft³ (0.079m³).

^dA total backlog of 704 HLW-glass canisters or 791 HLW-calcine canisters built-up before 1985 is worked off between 1991-1995 at the rate of 140.8 glass or 158.2 calcine canisters per year.

^eWaste projections apply to all of the reprocessing cycles: U + Pu, U only or Pu in HLW

Table 5-4

CLADDING WASTE RECEIVING RATES^{a,b} (CYCLES I and III)

<u>Year</u>	<u>Canisters^c</u>	
	<u>Annual</u>	<u>Accumulated</u>
1985 ^d	169	169
1986	674	843
1987	730	1573
1988	843	2416
1989	1011	3427
1990	1180	4607
1991	1966	6573
1992	2135	8708
1993	2303	11011
1994	2528	13539
1995	2753	16292
1996	2360	18652
1997	2585	21236
1998	2753	23989
1999	2978	26967
2000	3202	30169
2001	3427	33596
2002	3596	37192
2003	3820	41012
2004	3989	45001
2005	4157	49158
2006	4326	53484
2007	4270	57754
2008	4270	62024
2009	4213	66237
2010	4157	70394

^aCladding wastes for the U-recycle and U + Pu recycle cases.

^bBased on projections prepared by OWI (June-1977). Assumes a 480 GWe installed nuclear capacity by the year 2000 (5 year delay prior to burial).

^cReference canister is 10 feet long with a 1 foot diameter, containing 6.28 ft³ (.178m³) waste.

^dBacklog of 2809 containers in 1985 worked off during 1991-1995.

Table 5-5

ILW AND LLW RECEIVING RATES - U+Pu RECYCLE^a (CYCLE I)

<u>Year</u>	<u>ILW Canisters^b</u>		<u>LLW Drums^c</u>	
	<u>Annual</u>	<u>Accumulated</u>	<u>Annual</u>	<u>Accumulated</u>
1985 ^d	1404	1404	481	481
1986	5618	7022	1923	2404
1987	6180	13202	2404	4808
1988	5618	18820	3846	8654
1989	6742	25562	9135	17789
1990	5056	30618	6731	24520
1991	12191	42809	9808	34323
1992	11629	54438	11250	45573
1993	12191	66629	16058	61636
1994	13315	79944	16538	78174
1995	13876	93820	18462	96636
1996	8989	102809	21154	117790
1997	10674	113483	25000	142790
1998	11236	124719	28846	171636
1999	12360	137079	31731	203367
2000	13483	150562	37500	240867
2001	14607	165169	40865	281732
2002	16292	181461	46635	328367
2003	16854	198315	50000	378367
2004	18539	216854	57212	435579
2005	19663	236517	62500	498079
2006	20787	257304	68750	566829
2007	21348	278652	73558	640387
2008	22472	301124	80288	720675
2009	23034	324158	86538	807213
2010	23596	347754	88942	896155

^aBased on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity in year 2000 (5 year delay prior to burial).

^bILW Reference canister is 10 ft. long, 1 ft. diameter with an active volume of 6.28 ft³ (0.178m³).

^cLLW reference drum is a type 170,55 gallon (7.35 ft³ or 0.208 m³).

^dPrior to 1985 backlog of 30,056 ILW and 10,577 LLW canisters is accumulated. This backlog is worked off between 1991 and 1995.

Table 5-6

10-YR OLD SPENT FUEL RECEIVING RATES^a (CYCLE II)

<u>Year</u>	<u>PWR Canisters^b</u>		<u>BWR Canisters^c</u>	
	<u>Annual</u>	<u>Accumulated</u>	<u>Annual</u>	<u>Accumulated</u>
1985	139	139	454	454
1986	555	694	1814	2268
1987	979	1673	2124	4392
1988	1390	3063	2435	6827
1989	1657	4720	2524	9351
1990	1906	6626	2596	11947
1991	2336	8962	3723	15670
1992	2582	11545	4338	20008
1993	2953	14498	4814	24822
1994	3446	17945	5235	30057
1995	4045	21990	6021	36078
1996	4388	26378	6391	42469
1997	4976	31354	7520	49989
1998	5616	36970	8453	58442
1999	6270	43240	9422	67864
2000	6955	50195	10445	78309
2001	7637	57832	11436	89745
2002	8323	66155	12441	102186
2003	9026	75181	13498	115684
2004	9739	84920	14575	130259
2005	10506	95426	15734	145993
2006	11240	106666	16838	162831
2007	11953	118619	17903	180734
2008	12642	131261	18938	199672
2009	13301	144562	19910	219582
2010	13915	158477	20882	240464
2011	13939		20980	
2012	13932		20849	
2013	13932		20917	
2014	13932		20826	
2015	13932		20826	
2016	14043		20826	
2017	13877		20826	
2018	14008		20826	
2019	13812		21476	
2020	13928		20609	
2021	13951		21594	
2022	13951		21269	
2023	14261		21738	
2024	13728		21667	
2025	13428		21027	

^aBased on projections prepared by OWI (July-1977). Assumes 480 GWe by year 2000.

^bReference PWR canister contains 1 PWR assembly (0.461 MTHM).

^cReference BWR canister contains 1 BWR assembly (0.183 MTHM).

Table 5-7

SPENT FUEL - LLW RECEIVING RATES^a (CYCLE II)

<u>Year</u>	<u>Number of LLW Drums^b</u>	
	<u>Annual</u>	<u>Accumulated</u>
1985 ^c	208	208
1986	962	1170
1987	1093	2263
1988	1225	3488
1989	1363	4851
1990	1508	6359
1991	2438	8797
1992	2589	11386
1993	2741	14127
1994	2899	17026
1995	3056	20082
1996	2423	22505
1997	2575	25080
1998	2719	27799
1999	2866	30665
2000	3011	33676
2001	3147	36823
2002	3147	39970
2003	3147	43117
2004	3147	46264
2005	3147	49411
2006	3147	52558
2007	3147	55705
2008	3147	58852
2009	3147	61999
2010	3147	65146
2011	3114	
2012	3094	
2013	3081	
2014	3048	
2015	2995	
2016	2935	
2017	2057	
2018	2823	
2019	2782	
2020	2753	
2021	2700	
2022	2631	
2023	2553	
2024	2452	
2025	2315	

^aBased on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity by year 2000 and 13.7 m³ waste generated per GWe-yr. (With a compaction factor of 10).

^bReference drum is DOT type 17C 55 gal. drum containing 7.35 ft³ (0.208m³) of waste.

^cBacklog acquired before 1985 worked off between 1991-1995. Waste is shipped 1 year after generation - after the backlog is worked off.

Table 5-8

ILW AND LLW RECEIVING RATES^a - U RECYCLE (CYCLE III)

Year	<u>ILW Canisters^b</u>		<u>LLW Drums^c</u>	
	<u>Annual</u>	<u>Accumulated</u>	<u>Annual</u>	<u>Accumulated</u>
1985	1404	1404	481	481
1986	5618	7022	1923	2404
1987	6180	13202	2404	4808
1988	5618	18820	1923	6731
1989	6742	25562	2404	9135
1990	5056	30618	1923	11058
1991	12191	42809	4038	15091
1992	11067	53876	4038	19129
1993	12191	66067	4038	23167
1994	12753	78821	4519	27686
1995	13314	92135	4519	32205
1996	7865	100000	2885	35089
1997	8989	108989	2885	37974
1998	9551	118540	3365	41339
1999	10112	128652	3365	44704
2000	11236	139888	3846	48551
2001	11798	151686	3846	52397
2002	12360	164046	4327	56723
2003	13483	177529	4327	61050
2004	14045	191574	4808	65858
2005	14607	206181	4808	70666
2006	15169	221350	5288	75954
2007	15169	236519	5288	81242
2008	15169	251688	5288	86530
2009	15169	266857	5288	91818
2010	15169	282026	5288	97106

^aBased on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity in year 2000 (5 year delay prior to burial).

^bReference ILW canister is 10 ft. long, with 1 ft. diameter (6.28 ft³ or .178m³).

^cReference LLW container is a type 17C, 55 gallon drum (7.35 ft³ or .208m³).

^dBacklog of 30056 canisters ILW and 10575 drums LLW in 1985 to be worked off during 1991-1995.

Table 5-9
MINING PRODUCTION SUMMARY

<u>Cycle</u>	Max. Mining Machines Working <u>Simultaneously</u>	Max.Prod. Rate: Tons/Day/ <u>Machine</u>	Max. Tons <u>Mined/Yr.</u>	Max. Tons <u>Mined/Day</u>	Drilling: Max. Crew- Shifts/ <u>Day</u>	Sleeve Place- ment: Max. Crew Shifts/ <u>Day</u>
I	5	1500	2.25x10 ⁶	7500	40	14
II	4	2000	2.40x10 ⁶	8000	30	16
III	5	1500	2.25x10 ⁶	7500	40	14
II (25-Yr.)	4	1670	2.00x10 ⁶	6680	30	16
II (25-Yr. H.R.)	4	1670	2.00x10 ⁶	6680	*	*

* No drilling or sleeve placement on 25-year retrievability cases.

For sleeve placement operation: 10 men/crew
For drilling operation: 9 men/crew

Table 5-10
REPOSITORY TONNAGE SUMMARY
SALT

CYCLE	Tonnage Mined (x 10 ⁶)	Room Backfill Tonnage (x 10 ⁶)	Total Backfill Tonnage (x 10 ⁶) ^a	Off-Site Removal Tonnage (x 10 ⁶)	On-Site Storage Tonnage (x 10 ⁶) ^c	Backfill Tonnage Factor ^b
I	45	20	26	19	2	.594
II	35	17	20	15	1	.6
III	42	19	24	18	2	.594
II (25-Yr. N.H.R.)	37	*	*	37	*	*
II (25-Yr. H.R.)	48	*	*	48	*	*

- a. Total backfill is the tonnage mined less the tonnage associated with the trenches and drilled holes all multiplied by the backfill tonnage factor.
  - b. The backfill tonnage factor is the broken rock density divided by the inplace rock density times the percentage of room face area to be backfilled.
  - c. 60% of material excavated from rooms for 5-year capacity.
- * Backfill for the 25-year retrievable repository is not considered in this study.

Table 5-11
REPOSITORY SUMMARY - SALT
25-YEAR RETRIEVABLE CASES

<u>Cycle</u> <u>(Date</u> <u>Filled)</u>	<u>Waste</u> <u>Type</u>	<u>Capacity</u> <u>(No. Con-</u> <u>tainers)</u>	<u>Room</u> <u>Length</u> <u>(ft.)</u>	<u>Room</u> <u>Opening</u> <u>W x H</u> <u>(feet)</u>	<u>Approx.</u> ⁽¹⁾ <u>Area</u> <u>(acres)</u>	<u>No.</u> <u>Rooms</u>	<u>Waste</u> <u>Units/</u> <u>Room</u>	<u>Total</u> <u>No.</u> <u>Panels</u>	<u>No. Rooms per</u> <u>Panel/Panel</u> <u>Number</u>	<u>Longitud</u> <u>No.</u> ⁽²⁾ <u>Rows</u>	<u>Spacing</u> <u>ea. Row</u>	<u>Storage</u> <u>Configuration</u>
Cycle II (Heat Removal) (2004)	PWR	87,472	2910 3500	18 x 25	964	36 128	460 554	41	4/P #1 to 41	1	6' 3"	Can. in Trench
	BWR	137,117	1300 3500	18 x 25	810	36 120	382 1028	39	4/P #1 to 39	2	6' 9"	Can. in Trench
	LLW	60,192	1374	18 x 25	31	12	5016	3	4/P #1 to 3			Palletized Drum
Cycle II (Non-heat Removal) (2001)	PWR	60,400	2910 3500	18 x 25	1106	36 152	276 332	47	4/P #1 to 47	1	10' 6"	Can. in Holes
	BWR	95,992	1300 3500	18 x 25	568	36 80	382 1028	29	4/P #1 to 29	2	6' 9"	Can. in Holes
	LLW	40,128	1374	18 x 25	19	8	5016	2	4/P #1 to 2			Palletized drum

1) Approximate area is gross acreage associated with each storage section including main corridors, exhaust corridors and buttress pillars; it is not the net area used to calculate areal heat loads.

2) Refers to rows of canisters in each room.

TABLE 6-1

TYPICAL SUBSURFACE VENTILATING FAN SPECIFICATIONS

<u>Type</u>	<u>Nominal Capacity (cfm) per fan</u>	<u>Est. Total Pressure (inches of water)</u>	<u>Motor HP</u>
Main Supply Fans			
Cycles I and III	250,000	4	300
Cycle II, 5-yr. retriev.	215,000	4	250
Cycle II, 25-yr. retriev.	200,000	4	250
Cycle II, 25-yr. retriev. w/Heat Removal	260,000	4	300
Placement Operation Exhaust Fans	250,000	14	900
Mining Operation Exhaust Fans			
Normal Operation	600,000	4	500
Emergency Filtration	250,000	14	900

Table 6-2

ESTIMATED UNDERGROUND VENTILATION REQUIREMENTS
AT PEAK OF MINING AND PLACEMENT OPERATIONS

Waste Repository Type	Mining Operation Exhaust (cfm)	Placement Operation Exhaust (cfm)	Total Exhaust (cfm)	Exhaust Shaft Diameter/Air Velocity*
Salt (5-Yr.):				
Fuel Cycle I	1,250,000	250,000	1,500,000	26 ft/2970
Fuel Cycle II	1,100,000	250,000	1,350,000	26 ft/2650
Fuel Cycle III	1,250,000	250,000	1,500,000	26 ft/2970
Salt (25-Yr.):				
Fuel Cycle II	900,000	250,000	1,150,000	22 ft/3180
Fuel Cycle II	1,100,000	1,500,000 ^b	2,200,000 ^a	22 ft/2900 (Mining Exh.)
(Heat Removal)				24 ft/3315 (Placement & Heat Removal)

* Average velocity for mining and placement compartments.

a. Peaks of mining and placement do not coincide.

b. Includes heat removal from PWR rooms.

TABLE 6-3

SUBSURFACE AIR VELOCITIES

<u>Type of Airway</u>	<u>Air Velocity (fpm)</u>
Ventilation Shafts (Concrete lined, smooth surface)	2650-3180
Main Supply Air Corridors	
Cycles I & III	300-400
Cycle II, 5 & 25-yr. retrievable	200-300
Branch Corridors, carrying air for:	
Mining operation	150-250
Storage hole drilling	500
Backfilling	200
Storage Rooms, with	
Mining in progress	50-350
Waste placement in progress	Min. 50
Mining Air Exhaust Corridor	500-850
Placement Air Exhaust Airways	
Branch airways	200-400
Main airways	300-600
Heat Removal Exhaust Airways (Cycle II, 25-yr. only)	Max. 1500

TABLE 6-4

Canistered Waste Receiving Building
Confinement Zone Classifications
and Ventilation Design Requirements

Room	Confine- ment Zone	Room Pressure (Inches of water gage)	<u>Ventilation Criteria¹</u>	
			<u>Air Changes per Hour</u>	<u>Outside Air %</u>
Canister Storage and Feed Room	I	-1.00	2	-
Transfer Galleries	I	-1.00	6	-
Transfer Cells	I	-1.50	6	-
Operating Galleries	II	-0.10	6	100
Hoist Machine Room	II	-0.25	10	100
Service and Maintenance	II	-0.10	10	100
Cask Unloading	II	-0.10	3*	66
Exhaust Air Filter Room	II	-0.50	2	100
Mechanical Equipment Rm.	II	-0.10	6	100
Electrical Equipment Rm.	III	+0.10	6	100
Security Room	III	-0.10	10	100
Shift Foreman's Room	III	-0.10	10	100
Counting Room	III	-0.10	10	100
Chemical Lab.	III	-0.10	10	100
Health Physics Room	III	-0.10	10	100
Toilet Rooms	III	-0.10	10	-
Shower Rooms	III	-0.10	10	-
Locker Rooms	III	-0.10	10	100

*Overall ventilation rate for the total volume of Cask Unloading Rooms. Effective air change rate for the lower 25 ft. high portion of the room will be about six changes per hour.

1) Source:

Conceptual Design Report for Federal Repository,
 Lyons, Kansas prepared by Kaiser Engineers, Inc.
 (December 1971)

TABLE 6-5

Low-Level Waste Receiving Building
Confinement Zone Classifications
and Ventilation Design Requirements

Room	Confinement Zone*	Room Pressure (Inches of water gage)	Ventilation Criteria ¹	
			Air Changes per Hour	Outside Air %
Unloading and Parking	II	-0.50	10	100
Palletizing and Depalletizing	II	-0.50	10	100
Counting	II	-0.25	10	100
Inspection Room	II	-0.25	10	100
Decon. and Overpack	II	-0.25	10	100
Exhaust Fan Filter Room	II	-0.50	2	100
Hoist House	II	-0.10	10	100
Foreman's Room	III	-0.10	10	100
Health Physics	III	-0.10	10	100
Mechanical Equipment Room	III	-0.10	6	100
Electrical Equipment Room	III	+0.10	6	100
Battery Room	III	-0.10	15	100
Toilet Rooms	III	-0.10	10	-
Locker Rooms	III	-0.10	10	100
Janitor Closet	III	-0.10.	10	-

1) Source:

Conceptual Design Report for Federal Repository,
 Lyons, Kansas prepared by Kaiser Engineers, Inc.
 (December 1971)

* For a definition of confinement zone see Section 6.2.1.2

APPENDIX A

HOISTING SYSTEMS

A. Introduction

A total of six hoists will be installed in three of the shafts. Four will be tower mounted friction hoists, one will be a tower mounted drum hoist and one will be a ground mounted drum hoist. A list of permanent hoists is given below.

1. M & M Shaft

a. Skip Hoist

No: 1
Type: Friction
Mounting: Tower
Wheel Dia.: 11'-0"
No. Ropes: 4
Rope Size: 1 5/16" L.C.
RMS H.P.: 3,500 (S.C.)
RMS H.P.: 2,836 (F.V.)

S.C. - Self-Cooled
F.V. - Force Ventilated
L.C. - Locked Coil
F.S. - Flat Stranded

b. Cage Hoist

No: 1
Type: Friction
Mounting: Tower
Wheel Dia.: 11'-0"
No. Ropes: 4
Rope Size: 1 5/16" L.C.
RMS H.P.: 781 (S.C.)

Auxiliary Cage Hoist

No: 1
Type: Drum
Mounting: Tower
Wheel Dia.: 5'-0"
No. Ropes: 1
Rope Size: 3/4" F.S.
RMS H.P.: 160 (S.C.)

2. LLW Shaft

a. Cage Hoist

No: 1
Type: Drum
Mounting: Ground
Drum Dia.: 10'-0"
No. Ropes: 1
Rope Size: 1 1/2" F.S.
RMS H.P.: 1,000 (S.C.)

3. Canistered Waste Shaft

a. Cage Hoist

No: 2
Type: Friction
Mounting: Tower
Wheel Dia.: 16'-0"
No. Ropes: 5
Rope Size: 1 7/8" L.C.
RMS H.P.: 1710 (F.V.)
No. Tail Ropes: None

B. The LLW Shaft

The LLW Shaft hoisting system is designed for two different conditions:

1. Preliminary mining to be executed from the LLW Shaft requires the hoist to be capable of hoisting 2,000 TPD and lower a maximum load of 20,000 lbs.
2. Permanent use of this shaft requires the hoist to be designed to handle low-level pallets and waste containers with a maximum weight of 10,000 lbs.

During preliminary mining, ground mounted single drum hoist would be roped with two 1 1/2 inch flattened strand cables. An 11-ton capacity skip with a removable cage would be hoisted in balance with a counterweight. Hoisting speed is 1,200 FPM.

Once the M & M Shaft is completed; mining from the LLW Shaft will cease. At this time, the skip and counterweight would be removed, the guides arranged for the permanent cage and the permanent cage installed.

C. The Canistered Waste Shaft

The Canistered Waste Shaft hoisting system is designed to handle HLW, IL-TRU and CW from Cycles I and III and PWR/BWR canisters from Cycle II. The shaft will have two hoisting systems operating independently. Four canisters can be lowered by the cage of each hoist. The canisters are to be lowered in a specially designed cage having two in. thick stainless steel walls, a five in. thick lead core and a 1/4 in. steel plate liner retainer skin. The cage has a weight of 200,000 lbs. The cage will be hoisted in balance with a 200,000 lb. counterweight. Reliability of canister delivery to the repository will be ensured by providing dual cage counterweight systems.

The Canistered Waste Shaft is divided into two sections, with a separate hoist in each. The divider can be a concrete wall or a steel plate with intermittent doors to facilitate retrieval of malfunctioning equipment.

Due to the heavy loads to be hoisted, friction type hoists were selected. These hoists are tower-mounted over the Canistered Waste Shaft. In order to ensure safe operation of this facility, the shaft would be equipped with buntons at four ft. centers and the cages guided by elevator type guide rails. The cages would also be equipped with an elevator type braking mechanism designed to stop the cage during an overspeed condition.

D. Men and Materials Shaft

The Men and Materials Shaft hoisting system has been designed to meet the requirements of excavating the repository. Three separate hoisting systems are to be installed in a tower over the M & M Shaft.

Broken rock will be hoisted out of the mine at a rate of up to 12,000 TPD in two 16-ton capacity skips operating in balance. The hoist is a friction type with a wheel diameter of 11 ft. and a hoisting speed of 2,100 FPM.

Men and materials will be hoisted in a large cage designed to meet the following criteria:

1. Capacity to sling 26-ton gear box (heaviest piece) of mechanical miner.
2. Capacity to raise and lower diesel powered vehicles (maximum width 8 ft.).
3. Capacity to hoist at least 140 men in one trip.

The cage hoist will operate at a speed of 2,000 FPM. The wheel diameter is 11 ft. and is equipped with four 1 5/16 in. diameter cables. The cage will operate in balance with the counterweight.

An auxiliary cage will also be installed in the M & M Shaft. The purpose of this cage is to lower men and small items during the operating shift thus allowing the large cage to be scheduled to optimum use. The auxiliary cage hoist will have a capacity of 3,000 pounds or six men. The hoist is single drum, having a diameter of 5 ft., and a single 3/4 in. diameter cable.

E. Schedules

In the 5 yr. retrievable cases and the 25-yr. non-heat removal case five shafts have been designed to accommodate the excavation of an underground repository in salt and the placement of radioactive waste material. Four of the shafts are to be excavated using conventional drill and blasting shaft sinking techniques. The fifth shaft would be bored using a surface mounted drilling rig. The bored shaft is to be completed first, allowing preliminary mining in the repository to begin at an early date.

Construction of all five shafts would begin at the same time. An estimate of the time required to complete each shaft is shown in Table A-1 and Table A-2.

In the 25-yr. retrievable heat removal design two additional shafts are provided. One is a 17' diameter service shaft that would be used to lower the concrete and steel sleeves that are necessary to ensure retrievability to the repository level. This shaft takes 125 weeks to sink.

The second shaft would be an additional Exhaust Shaft that is necessary to remove a portion of the heat generated by the waste.

Table A-1 Excavated Shafts - Time in Weeks

Item	27'Ø M&M	26'Ø ^{1,2} SuA	26'Ø ^{1,3} ExA	14'Ø Can. Waste
1. Contractor's Mobilization	6	6	6	6
2. Collar & Headframe	39	24	24	36
3. Shaft Sinking, Station Cutting, Lateral Development	49	42	48	68
4. Grout Curtains, Drywall Steel Lining	49	45	45	41
5. Equip Shaft	9	3	5	7
6. Install Permanent Hoisting Equipment in Shaft	17	12	21	19
TOTAL	166	132	149	177

Table A-2 Bored Shaft - Time in Weeks

Item	10'Ø LLW
1. Contractor's Mobilization	6
2. Contractor's Setup, Foundations and Install Coving	4
3. Shaft Drilling, Lining and Grouting	40
4. Construct Permanent Headframe, Equip Shaft	18
5. Miscellaneous Excavation and Prepare for Development	20
TOTAL	88

1. 22' diameter for 25-yr. non-heat removal case.

2. 27' diameter for 25-yr. heat removal case.

3. Two Exhaust Shafts for heat removal case:

(1) 22' diameter for mining operation; and

(2) 24' diameter for placement operations and heat removal.

APPENDIX B

JOB CLASSIFICATION BREAKDOWN SUMMARY

SALT CYCLE II

	<u>Symbol</u>	<u>Number</u>
Supervisory and Clerical	A	102
Administrative and Management	B	163
Professionals	C	24
Skilled Labor	D	901
Miners	E	36
Semi-skilled Labor	F	232
Technicians	T	31
		<u>1,489</u>

The above figures correspond to the peak average daily man-shift requirements occurring in the year 2001 for the Salt Cycle II repository. Included in these figures are the personnel for the waste storage operation, mining operation, drilling operation, back-filling operation, and the mining production management group. Since the overall management and engineering requirements depend on the site selection, they are not included.

The Supervisory and Clerical category includes typists, secretaries, clerks and job supervisors. The accounting, employee relations, and public relations personnel are included under the Administrative and Management category.

The Professional classifications is for other positions requiring advanced education. This includes lawyers, engineers, health care personnel and job specialists. Those persons requiring some post high school professional training, such as lab personnel are classified as technicians.

Since miners are considered to perform unique functions, they are listed separately. The mining category includes mining machine operators, cable tenders, and task foremen. The Skilled Labor section consists of those assigned to operate any other mechanical devices, such as trucks, transporters or cranes. The Semi-skilled category comprises building custodians, food and clean-up services, and helpers to the skilled laborers.

An approximate classification breakdown summary can be obtained for any given year regardless of the fuel cycle by prorating the information given in the subsequent pages for the year 2001 with the values shown in the tables 1-2, 1-3, and 1-4 of the Salt Technical Report.

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
<u>I - Waste Storage Operation</u>		
Underground Storage		
a) LLW		
Shaft Crew	3	D
Forklift Drivers	4	D
Room Laborers	4	F
Equipment Maintenance	2	D
b) PWR/BWR		
Shaft Crew	12	D
Transporter Operators	16	D
Transporter Maintenance	8	D
Room Laborers	8	F
Crusher Crew	4	F
Maintenance Crews	5	D
Above Ground Storage		
a) High-Level Waste Bldg.		
Cask Washdown Crews	12	F
Bay Crane Operator	8	D
Bay Laborers	18	F
Bay Inspectors and Monitors	12	D
Transfer Cell Monitors	6	D
Transfer Cell Operators	40	D
Crane Operators	8	D
Hoist Operators	8	D
Lab Personnel	10	T
Mechanical and Electrical Services	10	D
Supervisors and Clerical	12	A
b) Low-Level Waste Bldg.		
Crane Operators	1	D
Transfer Cell Laborers	3	D
Fork Lift Drivers	3	D
Inspectors and Testers	3	D
Lab Personnel	3	T
Maintenance	2	D
Supervisors and Clerical	3	A
c) Control Room		
Monitoring and Scheduling Personnel	18	B
d) Railroad Operations		
Operations Personnel	23	D
Equipment Maintenance	17	D

*for Job Classification definitions see "Job Classification Breakdown Summary"

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
e) Shipment Inspections Handling and Warehouse Operations	12	F
f) Liquid Rad Waste		
Crane Operators	3	D
Lab Personnel	5	T
Mechanical and Electrical Service	2	D
Supervisors and Clerical	2	A
Support Activities		
a) Ventilation Maintenance	9	D
b) Boiler, Refrigeration, Coal Handling Labor and Maintenance	16	F
c) Motor Pool and Fuel Depot Operations Personnel and Maint.	6	F
d) Maintenance		
Roads and Grounds	4	F
Building	4	F
Equipment	6	D
Electricians	8	D
Utilities	6	D
Instrument Repair	4	D
Custodial	12	F
e) Security		
Administration Building	8	D
Main Gate	8	D
Railroad Gate	4	D
Control Room	4	D
High Level Waste Building	4	D
Patrols	15	D
Underground	49	D
Badge Checkers	6	D
Security Chief	3	D
Clerical	2	A
f) Miscellaneous		
Lanundy	8	F
Cafeteria	9	F
Change House	10	F
Fire Protection	22	D
Radiation Safety	18	D
Administration and Management	<u>119</u>	B
Total of Waste Storage Operation	674	

*for Job Classification definitions see "Job Classification Breakdown Summary"

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

II - Mining Operation

<u>Section</u>	<u>Type</u>	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
Mining @ Face	Foreman	12	E
	Machine Operators	12	E
	Cable Tenders	12	E
	Machine Maintenance	24	D
Underground Haulage	Truck Drivers & Conveyor Tenders	51	D
	Loader Operators	12	D
Hoisting	Shaft Superintendent	3	D
	Bin Tenders	6	D
	Conveyor Operators	12	D
	Skip Tenders	3	D
	Hoistmen	3	D
	Cage Tenders	3	D
	Signal Men	9	D
	Helpers	12	F
Disposal	Equipment Operators	29	D
Support	Roadway Maintenance and Equipment Repair	8	D
	Ventilation Maintenance and Repair	22	D
	Electricians	30	D
	Mining Equipment Maintenance	12	D
	Truck Maintenance	16	D
	Hoist Maintenance	9	D
	Machine Bit Maintenance	17	D
	Utility Maintenance	10	D
	Roof Support	1	D
	General Labor	46	F
	Supervisors and Clerks	<u>56</u>	A
Total of Mining Operation		430	

*for Job Classification definitions see "Job Classification Breakdown Summary"

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

III - Drilling

<u>Section</u>	<u>Type</u>	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
Drilling	Foreman	17	D
	Drill Operators	51	D
	Helpers	33	F
	Machine Repair and Maintenance	<u>110</u>	D
	Total of Drilling Operation	211	

IV - Backfill

Backfill	Conveyor Tenders	30	D
	Dozer Operators	<u>6</u>	D
Total of Backfill Operation		36	

*for Job Classification definitions see "Job Classification Breakdown Summary"

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
<u>V - Mining Production Management Group</u>		
A) Engineering		
Chief Engineer	1	C
Industrial Engineer	1	C
Ventilation Engineer	1	C
Electrical/Mechanical Engineers	3	C
Mining Engineer	1	C
Junior Engineers	8	C
Technicians	13	T
Ventilation Instrument Men	4	D
Chief Planner	1	C
Chief Draftsman	1	D
Draftsmen	3	D
Chief Surveyor	1	D
Surveying Party Leaders	4	D
Surveying Instrument Men	4	D
Surveying Rod Men	4	F
Surveying Clerks	4	D
Typists	2	A
Secretary	1	A
B) Accounting		
Accounting and Service Mgr.	1	B
Budget Director	1	B
Services Coordinator	1	B
Warehouse Supervisor	1	A
and Workers	10	F
Public Coordinator	1	B
Material Buyers	2	B
Data Processing Coordinator	1	B
Data Processing Supervisor	1	B
Programming Supervisor	1	B
Computer Operators and Programmers	5	D
Accounting Supervisor	1	B
Cost Accountant	2	B
Payroll Accountant	1	B
Clerks	11	A
Typist	2	A
C) Employee Relations Dept.		
Manager	1	B
Security Officer	1	B
Guards	8	D

*for Job Classification definitions see "Job Classification Breakdown Summary"

JOB CLASSIFICATION BREAKDOWN

SALT CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
C) Employee Relations Dept. (cont'd.)		
Safety Director	1	B
Engineers	3	C
Industrial Hygiene	1	C
Clerk	1	A
Training Director	1	B
Training Coordinator	1	B
Employee Relations Specialist	1	C
Employment Relations	3	B
Labor Relations Specialist	1	C
Benefits Specialist	1	C
Clerks	3	A
Secretary	1	A
Receptionist	1	B
Typists	2	A
D) Miscellaneous		
Legal Advisor	1	C
Planning Coordinator	1	B
Public and Government Manager	1	B
Public Relations	2	B
Typists	<u>3</u>	A
Total of Mining Production Management Group	138	

*for Job Classification definitions see "Job Classification Breakdown Summary"

APPENDIX C

ALTERNATIVE CANISTER EMPLACEMENT SCHEMES

I. INTRODUCTION

As part of this preconceptual design study, alternative schemes were explored for ensuring 25-year retrievability of Spent Unreprocessed Fuel (SURF or Cycle II) nuclear waste material stored in deep geologic deposits of bedded salt. The engineering design needed to permit 25-year retrievability of spent fuel waste from BWR's (boiling water reactors) and PWR's (pressure water reactors) must take into account the constraining characteristics of the salt medium. In particular, because salt exhibits pronounced creep behavior at elevated temperatures, room and pillar design has to allow for the creep phenomenon by over-sizing some underground opening dimensions, without compromising the long-term structural integrity of the underground facility. Similarly, canisters cannot be emplaced without extra protection from the nearby salt formation because corrosion due to brine inclusions and the formation of HCL would destroy their integrity. Other constraints of the design problem include:

- o Mine Layout. Size of rooms and pillars and their arrangement will affect the location and spacing of the canisters.
- o Heat Generation. The allowable thermal loading per acre for the total repository as well as localized thermal loadings are determined from the predicted thermomechanical response of the repository. This also affects canister spacing and arrangement.
- o Canister Characteristics. The characteristics shown in Table C-1 were furnished by Science Applications, Inc.

Various alternative waste emplacement schemes were examined in terms of engineering feasibility, ventilation requirements, and cost. Efforts were concentrated on alternative canister orientations and alternative protective materials. All together, eight canister orientations were examined: vertical in the ceiling of the room, horizontal in the pillars, at an angle in the walls, free standing on racks, and four alternative arrangements for vertical in the floor. Other alternative horizontal and vertical emplacement concepts are treated in Reference 1.

Metals, composites, ceramics, and metal alloys were investigated as candidate materials for protecting the canisters from the salt environment. Various concrete and spun rock sprays were considered for protection of the openings housing the canisters.

The basic canister configuration for BWR and PWR spent fuel is shown in Figure C-1.

II. CANISTER OPERATION

A. Vertical in the Ceiling of the Room

Canisters would be placed in 24 in. diameter holes in the ceilings of the rooms, spaced according to local and overall heat generation requirements. A 1-1/2 in. carbon steel liner would be provided around the canister in order to protect it against corrosion. Once the canister is situated in the hole, a concrete plug would seal it in place. Although the rooms would be ventilated, the formation absorbs all of the heat under this scheme; there would be no direct ventilation of the canisters.

Canisters vertically emplaced in the ceiling are less susceptible than other emplacement schemes to corrosion from brine inclusions* originating from underlying aquifers. Despite this low susceptibility to corrosion from brine inclusions, the vertical emplacement option was given no further consideration because of several drawbacks: first, a special transporter would need to be designed in order to turn the canister upside down, slide it into the hole, and maintain it there while the plug is placed. The second drawback is the possibility of the canister falling out of the hole and sustaining some damage which could lead to contamination of the mine.

B. Horizontal in the Pillars

Canisters would be stored horizontally in 24 in. to 36 in. diameter holes in the pillars connecting adjacent rooms. A carbon steel sleeve encloses the canister and a steel liner borders the hole. Adjacent rooms would be maintained at different pressures and space left between the canister and the walls of the hole in order to let ventilating air flow around the canisters from one room to another. This arrangement is shown in Figure C-2.

The ventilation by forced convection, however, would take up only a fraction of the heat, the rest being absorbed by the formation. As a result, direct heat would be absorbed by the pillars, accelerating their creep rate.

* Solubility of salt increases with increasing temperature. A brine inclusion close to a hot spot in the salt formation will absorb the hotter salt until it becomes supersaturated. It is then closer to the heat generating source and therefore at a higher temperature and able to absorb still more salt. As the brine inclusion migrates progressively towards the source, the formation is slowly eroded, causing potential corrosion problems because brine subjected to radiation will form large quantities of hydrochloric acid.

In addition, overburden pressure would concentrate stresses around the holes in the pillars. These two phenomena would cause the steel sleeve to deflect to such a degree as to exert binding pressure on the canister. The result of this binding pressure would be either to jam the canister in the sleeve, preventing retrievability, or to fracture the canister. This possibility is sufficient cause to reject this emplacement scheme.

C. At an Angle in the Walls

This alternative consists of drilling holes at 45 degree angles in the walls of the rooms. Spacing would be determined to satisfy heat generation requirements. Canisters would not be ventilated but would be provided with a 1-1/2 in. thick sacrificial carbon steel sleeve. Concrete plugs would seal the canisters in place.

Little further consideration was given to this option because there are no advantages associated with it relative to placing the canisters vertically in the floor of the storage rooms, and because a special transporter feature would be required to tilt the canisters 45 degrees and slide them into the openings. Additional information on this option is available in Reference 1.

D. Free Standing on Racks

Canisters would be stored vertically on racks to avoid direct contact with the salt. This emplacement scheme eliminates for the most part the corrosion problem. Although the canisters would still be in a corrosive environment since the air contains a high percentage of salt, the potential attack would be limited. The rooms would be sealed off when full and would not require ventilation until reopening.

This option, despite its simplicity and low cost, is not an attractive one: if the rooms must be reopened in order to retrieve their contents, special transporters would have to be designed to shield the operators. Otherwise, retrieval would not be possible because of radiation emissions.

E. Vertically in the Floor

Four alternative arrangements were examined under this waste emplacement scheme. These can be divided into two categories:

1. Non-heat Removal -

- a. Storage of BWR and PWR in holes drilled in the mine floor.

2. Heat Removal -

- a. Storage of PWR and BWR in forced-ventilated trenches
- b. Storage of PWR and BWR in free-ventilated holes
- c. Storage of PWR and BWR in free-ventilated trenches

1. Non-Heat Removal - Storage in Holes in the Mine Floor. The 25-year retrievability option shown in Figure C-3 is an extension of the five year retrievable case described in previous chapters. In the five year case, the waste is retrievable for five years after emplacement in the mine. The canisters are stored vertically in 24 in. diameter holes for PWR and 20 in. diameter holes for BWR, drilled in the room floors. Once the rooms are filled they would be sealed and all ventilation stopped until the room is reopened. A 3/8 in. thick sacrificial carbon steel sleeve is provided to protect them from corrosion and permanent encasement in the salt due to creep.

For 25-year retrievability the sleeve thickness would be increased to 1-1/2 in. This thickness, chosen to prevent corrosion of the canister and to ensure its structural integrity, was furnished by OWI. In this option, PWR would be placed in holes 26 in. in diameter and 25 feet deep, spaced 10 ft.-9 in. on center down the centerline of the rooms. BWR would be positioned in two rows in holes 22 in. in diameter and 25 feet deep. The rows would be 6 ft.-9 in. apart on center longitudinally and 6 ft. on center laterally. Once a canister is in place, a concrete plug covers the entire opening and the hole would then be backfilled with salt. When the room reaches maximum canister capacity, it is sealed and all ventilation stopped. As a result, the formation absorbs 100% of the heat generated by the canisters.

2. Heat Removal Storage in the Mine Floor. Retrievability hinges on two temperature dependent factors: corrosion and creep around the canister. If all the heat generated by the canister is removed, the rate of creep will decrease and the migration of brine inclusions towards the heat source lessened. The surrounding salt formation would then be left as the only corrosive agent. Three alternative ventilation schemes for removing heat are described below.

a. Storage in Forced Ventilation Trenches - A 20 ft. deep trench would be excavated along the centerline of the rooms. Concrete pipes, approximately two feet in diameter, would be placed single file in the trench and the canisters lowered into them. Ducts along the bottom of the trench would be used to force air past the canisters into the rooms, convecting heat to the surface. The canisters would be continuously ventilated over the 25 year period of retrievability. There are several deficiencies to this scheme (shown in Figure C-4):

- o Installation and maintenance costs are high;
- o The ducts might malfunction if there is water inflow or high humidity within the facility;
- o Maintenance will probably be impossible due to the radiation emissions from the canisters.

b. Stored in Holes - Free Convection - Holes 58 in. in diameter would be drilled in the salt as shown in Figure C-5. A double concrete prefabricated pipe would be installed in the hole and the canisters would be placed in the center of the pipe. Continuous ventilation in the rooms would supply the air needed for convection. The temperature field around the canister causes the air to circulate down the outer ring and up the inner one, taking with it most of the heat generated by the canister. There are several drawbacks to this scheme:

- o It is questionable whether the outer concrete sleeve would add significantly to the protection of the canister and thereby justify its cost. The walls of the pit could instead be coated - to protect them against radiation and the drying effects due to air circulation - at a fraction of the cost of the concrete sleeve.
- o The size of the holes prevents maximum canister capacity in terms of allowable kilowatts per acre for the overall facility. Since heat is being removed under this option, the canisters can be placed closer together. Therefore, the maximum heat load per acre is constrained by the spacing of the holes rather than by the areal heat loading.

- o Five ft. wide holes cannot be drilled in one pass. Instead, several holes two ft. wide must be drilled. However, this process is very costly.

c. Storage in Trenches - Free Convection - A trench 5 ft. wide for PWR and 7 ft. 6 in. wide for BWR would be mined along the centerline of the rooms. PWR would be placed single-file 6 ft. 3 in. on center*, and encased in concrete pipes 2 ft. 2 in. inside diameter, 3 ft. 4 in. outside diameter. The canisters would also be provided with a 3/8 in. steel sleeve for added protection against the salt environment. Concrete plugs would be used to seal the canisters individually (see Figure C-6).

The rooms would be continuously ventilated over the 25 year retrievability period. The temperature field around the canister causes the air to circulate down the outer ring through four inlets and up the inner ring, taking with it 50% of the heat generated by the canister. The remainder of the heat would be absorbed by the formation. The sides of the trench would be sprayed with a heat protective coating, such as spun rock, to ensure that the surface does not dry out or flake due to air circulation. To minimize the creep of the trench walls, a bracing system is shown installed at the top of the trench.

BWR canisters would be placed in the configuration shown in Figure C-7. The BWR canisters are placed closer together than the PWR because their average heat generation rate per canister is lower. In fact, the spacing selection for the BWR canisters may altogether obviate ventilation of storage rooms containing this waste type.

F. Summary of Emplacement Schemes

As a result of this investigation, two canister emplacement schemes were found to be suitable: the non-heat removal hole configuration and the free convection-trench configuration. Both these options require no special transporter design, no maintenance, and present no mining difficulties.

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* Note that the canisters can be spaced considerably closer than in the non-heat removal scheme.

III. PROTECTIVE MATERIALS

If canisters are to be retrievable for 25 years after emplacement, they must be protected against corrosion and their openings must be protected against creep of the formation. The problems of controlling creep and maintaining the structural integrity of the openings have been addressed previously. In this section, two ways are discussed in which the canisters and the surrounding salt can be protected from each other:

- o Protective sleeves around the canister
- o Protection of the openings, whether holes or trenches.

The material to be selected must satisfy the following criteria: withstand temperatures of up to 200 degrees F.; not disintegrate under radiation; and resist corrosion by brine and hydrochloric acid. The 25 year retrievability, non-heat removal scheme, the worst design case because of its high heat and highly corrosive environment, is the one used as the reference case for this discussion. Many materials were considered but few proved to be acceptable for protection against both brine and HCL.

A. Sleeve Materials

1. Steel. In a previous study² it was recommended that a stainless steel liner be placed around the canister. Steel will not disintegrate under radiation, it has fair resistance to acids, and it has a good thermal shock resistance. Because stainless steel cracks at temperatures approaching 200 degrees F., carbon steel was found to be preferable. Carbon steel has essentially the same properties as stainless, but it is not prone to heat cracking. Due to the high cost of steel, however, a study was made of possible alternative materials to be used as liners.

2. Composites. A composite is an array of fibers embedded in a matrix. The first alternative to be considered was an organic matrix composite. Since epoxies are permeable and can absorb up to six percent of their weight in water, they were deemed inadequate and a metal matrix was then examined. Although several metal matrix composites are available, those utilizing a graphite filament were rejected because, as a conductor, graphite would subject the matrix to galvanic corrosion. Boron, not being a conductor, can be

used with an aluminum matrix, for example, without subjecting it to galvanic corrosion. In addition B/AL (Boron-Aluminum) can withstand temperatures on the order of 500-600 degrees F. As with most composites, B/AL is strong with an ultimate strength in tension of approximately 100,000 psi, and has good thermal shock resistance. On the other hand, the emission of neutrons could lead to degradation of the material by affecting the boron/aluminum interface. Furthermore, aluminum is very vulnerable to hydrochloric acid and although the material could be clad to protect the aluminum from coming in contact with acids, this material is not recommended because of its unreliability, as well as its high cost.

Since resistance to hydrochloric acid is one of the most difficult constraints to satisfy, emphasis was placed on materials that can withstand attack by HCL. One such group of materials is ceramics.

3. Ceramics. Four possible ceramics were considered: Beryllium Oxide (BeO), Silicon Carbon (SiC), Silicon Nitrate (Si_3N_4), and Maycore, a brand name, containing 50% silicates, 41% aluminum, and 9% boron. All of the above have good thermal shock resistance, and their thermal conductivity is on the order of 60 BTU/hr. Their tensile and compressive strengths are high with the bending-strengths ranging from 10,000 to 25,000 psi. As ceramics, their resistance to HCL is excellent.

There are several drawbacks, however, associated with using a ceramic material. At high temperatures Beryllium Oxide is vulnerable to attack by water vapor ($\text{BeO} + \text{H}_2\text{O} = \text{Be}(\text{OH})_2$), which slowly erodes the material. In addition, radiation decreases the thermal conductivity of all ceramic materials. This in turn reduces the thermal shock resistance and may cause the material to crack, exposing the canister to corrosion. For these reasons, ceramics were discarded as a realistic sleeve material.

4. Metals/Alloys. The following metal/alloys were considered: Hastelloy B, Monel, Titanium, Zirconium, and Alclad. Hastelloy B is composed of 61% nickel, 28% monel, 5.5% iron, and 1% Chromium. It has unusually high resistance to all concentrations of HCL at elevated temperatures. Unfortunately, oxidizing acids and salts rapidly corrode it. Furthermore, work hardening presents fabrication difficulties which make it more expensive than steel.

Monel, a nickel based alloy, has a corrosion resistance superior to its components. It will not, however, stand up against very oxidizing or reducing environments.

Titanium's resistance to salt water is much superior to stainless steel and it will resist hot chloride solutions as well. However, it has a prohibitively high cost (15 times that of steel), and difficulties associated with fabrication.

Zirconium is similar to Titanium although it is not quite as expensive, between \$5 and \$7.50/lb. for sponge.

Alclad has many of the advantages of steel: good bending, tensile and compressive strengths; good thermal conductivity; and moderate price. In addition, it is light-weight - a factor which influences the selection of hoists. The main problem associated with unclad aluminum is its high vulnerability to attack by HCL and brine. Even though aluminum can be clad, several problems persist in spite of the cladding:

- o Cladding must be insufficient to withstand high concentrations of both HCL and brine;
- o The cladding might crack at high temperatures or otherwise not protect the aluminum fully for 25 years;
- o There is a possibility of galvanic corrosion if the cladding is a metal, or of stress corrosion if the sleeves are highly stressed.

Based on this study it was concluded that carbon steel would be the best material for satisfying the sleeve design constraints associated with 25-year retrievability. The thickness for non-heat removal is 1-1/2 in. and requires no cladding. For the 25 year heat removal case a nominal thickness of 3/8 in. is required. Finally, the costs associated with carbon steel are favorable compared to the costs of the other materials investigated.

B. Protection of the Openings

The concrete pipes around the canisters serve a double purpose: first, they are an integral part of the ventilation scheme, directing the air (because of temperature differences) down the outer annulus and up the inner one.

Second, they partially shield the walls of the holes and trenches from radiation.

Several concrete types were considered. Type Q, commonly used in nuclear power plants, has a high compressive strength (8,000 psi) which will not decrease when subjected to temperatures of 500 degrees F. Although HCL will disintegrate concrete, brine will not affect its integrity as long as environmental conditions do not fluctuate between wet and dry.

Another type of concrete considered was Iron Oxide Mortar (Fe_2O_3), manufactured by Chemtree Corporation. It is also used as shielding against radiation in nuclear reactors and can withstand temperatures higher than regular concretes. Its compressive strength is on the order of 7,000 psi at all slumps.

One of the advantages of Iron Oxide Mortar over concrete is that the concrete components can be varied to meet specifications. As an example, the amount of Portland cement (type #5) in the matrix can be varied to provide better resistance to HCL. This option would be more expensive than Type Q concrete.

For additional protection, the walls of the trench could be sprayed. Since holes would be backfilled with salt, they would not need to be sprayed. So far the best candidate appears to be a spun rock spray, Spraycraft C manufactured by Spraycraft Corporation. In addition to maintaining strength when coming in contact with water up to temperatures of 300°F., and having good flexibility (to ensure minimum cracking due to creep of walls), it will adhere to salt and will not flake. This implies no maintenance or respraying will be required during its expected 25 year life. This spray would protect the walls of the trench from both radiation and drying (i.e., flaking) due to the air circulation. Costs for spraying have not yet been determined but they do not seem to be prohibitive.

REFERENCES

1. High Level Waste Canister Emplacement and Retrieval Concepts Study, OWI Report No. Y/OWI/SUB-76/16509, Prepared by the Boeing Company, September 1976.
2. Waste Isolation Facility Description for the Spent Fuel Cycle - Bedded Salt, OWI Report No. Y/OWI/SUB-77/16543, Prepared by Parsons Brinckerhoff Quade & Douglas, Inc., May 1977.

CANISTER CONFIGURATION

N.T.S.

Fig. C-1

HORIZONTAL STORAGE CONFIGURATION

**Non Heat Removal
CANISTER PLACEMENT ELEVATION**

TRENCH CONFIGURATION FORCED CONVECTION

Fig. C-4

PWR/ALTERNATE 1

HOLE CONFIGURATION
FREE CONVECTION

Fig. C-6

Fig. C-7

TABLE C-1

SPENT FUEL CANISTER CHARACTERISTICS

WASTE TYPE	PWR	BWR
Age at burial (years)	10	10
Power (kw/can) max./avg.	1.0/.55	1.0/.177
O.D. (inches)		
w/o overpack	14	10-3/4
w/ overpack	16	12-3/4
Lengths (feet)		
w/o overpack	16	16
w/ overpack	16 1/2	16 1/2
Weight (lbs)		
w/o overpack	910	480
w/ overpack	1650	1060
Radiation (rems/hr. at surface of can.)		
Neutrons	0.35	0.25
Gamma Rays	7×10^4	5×10^4