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TECHNICAL SUPPORT FOR GEIS:
RADIOACTIVE WASTE ISOLATION
IN GEOLOGIC FORMATIONS

MASTER

Volume 12

Repository Preconceptual Design Studies: Shale

April 1978

Prepared By

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UNION
CARBIDE

OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

*prepared for the U.S. DEPARTMENT OF ENERGY under
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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

*These documents were prepared by Science Applications, Inc. (SAI), 800 Oak Ridge Turnpike, Oak Ridge, Tennessee 37830; Dames & Moore (D&M), 20 Haarlem Avenue, White Plains, New York 10603; and Parsons Brinckerhoff Quade & Douglas, Inc. (PBQD), One Penn Plaza, New York, New York 10001.

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ABSTRACT

This volume, Volume 12 "Repository Preconceptual Design Studies: Shale," 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 shale. 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-36/13, "Drawings for Repository Preconceptual Design Studies: Shale."

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

*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: Shale," 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 shale 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. Once the storage rooms are backfilled, the surface facilities would be decommissioned and dismantled, and all shafts would be plugged and sealed.

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) containing 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 the 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 wastes, 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.² 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 waste 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 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 wastes.

1.4 Geotechnical Factors That Influence Design³

Because of geological characteristics and the general stratigraphic setting for shale, a repository in shale will influence many of the design and layout features of the surface and subsurface facilities as well as the amount of waste that can be stored. The characteristics that would significantly impact the design of the waste storage facility include:

- o Effects of heat on rock strength
- o Rock movement
- o Room and pillar stability
- o Groundwater movement.

1.4.1 Effects of Heat on Rock Strength

At high temperatures, the strength of rock is diminished as the rock structures begin to break down. In shale, major losses of strength are expected to occur at around 200°C to 300°C. To prevent severe 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 large volumes of rock in the immediate vicinity of 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 rock surrounding and overlying the repository would react or move in response to the stresses imposed by the mined excavation and by thermal loading from the implanted waste materials. 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 Room and Pillar Stability

1.4.3.1 Room Stability

Shale is not as plastic as salt but is less brittle than granite or basalt. It tends to fail slowly when overstressed and

after failing it loses a large portion of its strength. The general integrity of a room can be preserved if potential unstable zones are supported as soon as possible to eliminate progressive failure. Taking these factors into account, the following tentative room stability guidelines have been established.

If the calculated strength to stress ratio in a unit rock mass cube (dimensions equal to 20% of the mean room diameter) at the room periphery is two or greater, no support is required except in isolated areas where loose rock is observed. If the calculated strength to ratio drops below two, continuous support, engineered to maintain acceptable integrity of the rock mass, should be used. With support present, theoretical analyses should show that no compressive failure (strength to stress ratio less than one) of a volume greater than one unit rock cube occurs in the crown or roof of the opening. No failures in the side walls are permitted.

1.4.3.2 Pillar Stability

For a shale repository design, calculations should show that the mean stress to strength ratio for the entire pillar is greater than two.

1.4.4 Groundwater Movement

Based on the generic shale stratigraphic section (Dwg. 22 in all sets) the repository shafts will penetrate some waterbearing gravel and sandstone layers above the waste storage level. Depending on site specific permeabilities, inflow of water into unlined shafts would be tens of gallons per minute (gpm) to several hundred gallons per minute.⁴ Accordingly, these aquifers will have to be carefully sealed to prevent possibilities of water entering into the repository.

Based on theoretical calculations, it is estimated that total inflow into the repository through the shale host rock will be

from 50 gpm initially to 700 to 1,500 gpm at the final stages of the facility operation.⁵ (These calculations did not take the offset of heat into consideration.) This water would be pumped to the surface, tested for contamination, and, if not contaminated, would be discharged to the storm water runoff system. Techniques for handling this water if it is contaminated have not been designed but would have to be addressed prior to the establishment of the repository.

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. They would be working in three eight-hour shifts per day, 250 days per year. 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

Mining the repository in shale would be done by the conventional mining methods of drilling, blasting, load-hauling, and roof bolting. Two-boom drill jumbos would be used to drill holes for the placement of charges. After detonation, the blasted material would be dumped into a feeder-breaker (crusher) at the end of a belt conveyor in each panel.

Extendible conveyors would be used in the panels to permit rapid advance of the mining operation. These conveyors would be suspended from the roof once they leave the feeder-breaker area in order to allow mine vehicles to move more freely, particularly in the panel entries. The panel conveyors would discharge onto the main conveyor located in main corridor system for transport to a central crusher. Here the material will be further crushed, then conveyed to skip loading pockets, and finally hoisted to the surface for disposal.

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 - Shale, Y/OWI/TM-36/6, Oak Ridge, Tennessee, April 1978. Chapters 2 and 9.
4. _____, Stratigraphies of Salt, Granite, Shale, and Basalt, Y/OWI/TM-36/3, Oak Ridge, Tennessee, April 1978 Chapter 4.
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
- 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 facility:

- 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 wastes, 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's 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 containing 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 the 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 flatbed 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 fil-

ter cartridges and noncombustible materials (concrete, mortar, etc.), small discarded equipment, metal filters and metal encased HEPA filters.

Liquids. Sources of liquid radwaste would be 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 makeup area. A potential source of liquid radwaste would be the mine water inflow. In the unlikely event that this groundwater, pumped from the storage areas, were to become contaminated by contacting waste containers, treatment of this water could be required before it met water quality standards for liquid discharges to the environment.

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 tanks and equipment necessary to 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.

A treatment system for removing radionuclides from the mine water, if necessary, would consist of a sampling and holding pond, an optional pretreatment process to remove hardness, a cation exchanger and an anion exchanger. The building for this system would be larger than one described for other liquid radwaste due to the larger flow volumes that could require treatment; however, the support facilities, such as drumming station, personnel areas and truck access areas, would be similar in size.

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, the Canistered Waste Receiving Building, the incineration and 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 reused 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 towers operating from 85° F to 105° 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.

2.2.4.3.3 Groundwater Treatment Process

Water pumped from the mine would be held in a surface pond and sampled for radioactivity. This holding pond would be equal in size to about four to six daily flow volumes. In the event the activity concentration in the water was above applicable water quality standards the water would pass through the treatment system. The first stage would be an optional pretreatment process to remove hardness in the form of Ca and Mg ions if they existed in sufficient quantities to hinder the operation of the ion exchange beds. The next two stages consist of cation and an ion exchange beds which remove the radionuclides from the water. One stage of each type of ion exchange bed would be sufficient to obtain the recommended decontamination of 1×10^2 . A detailed description of the need for and operation of this system, up to the ion exchanger stages, can be found in Y/OWI/TM-36/21, Groundwater Movement and Nuclide Transport.

The remainder of the system would consist of a liquid solidification process and a drumming station similar to that described in Section 2.2.4.3.2 for the treatment of other liquid radwastes.

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, diethylene phthalate (DEHP) 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 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

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

The building will house the exhaust fans and filters required for the continuous filtering of the exhaust air from the subsurface waste placement operations in the storage rooms as well as the exhaust fans associated with the mining and drilling operations. In addition, space is provided 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 bridge cranes.

2.2.6 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.

2.2.7 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.

2.2.8 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.

2.2.9 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.

2.2.10 Mine Operations Building

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

2.2.11 Main Substation

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

2.2.12 Emergency Generator Building

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

2.2.13 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.

2.2.14 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.

2.2.15 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.

2.2.16 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 Receiving 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.

2.2.17 Fire House

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

2.2.18 Water Tank

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

2.2.19 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 railroad traffic into and out of the high security area.

2.2.20 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.

2.2.21 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.

2.2.22 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: Shale, Y/OWI/TM-36/13, Oak Ridge, Tennessee, April 1978.
2. Y/OWI/TM-36/21, Nuclear Considerations for Repository Design, 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 the 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 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

Steam at 200 PSIG is assumed to be 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.

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

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, though 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 SHALE

4.1 General Description

In these designs, five distinct shaft structures would be sunk using conventional techniques. These are the Canistered Waste Shaft, the Low-Level Waste 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 Dwg. 31 in all sets. These repository designs are shown in Table 4-1.

In the study being considered, five shafts are to be excavated from the the surface to the repository horizon. Because the placement schedule could be delayed if the underground initial development had to wait for the permanent Men and Materials 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 area to deliver 100,000 cfm of fresh air. The plan selected to satisfy these requirements is to sink one of the shafts from the 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 has been listed 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 ft. of concrete except where aquifers are encountered. At such interfaces extra measures, such as steel liners or grout, would be incorporated. 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 Dwg. 34 in all sets.

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 whether 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 Dwg. 35 in all sets. The Canistered Waste Safety Mechanism is shown in Dwg. 36 in all sets.

4.2.2. Low-Level Waste Shaft

The Low-Level Waste Shaft provides 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. (See Dwg. 37 in all sets).

4.2.3 Man and Material (M&M) Shaft

A Man and Material Shaft is designed to handle mine and storage personnel and mined material removal. The shaft is designed to accommodate 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 of this cage 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. The M&M Shaft is shown in Dwg. 32 in all sets.

4.2.4 Ventilation Supply Shaft

Ventilation air for the underground areas would be received through this shaft. (See Dwg. 39 in all sets). Prior to receipt, the air would 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 underground 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. The shaft is shown in Dwg. 40 in all sets.

4.3 Conventional Shaft Sinking Techniques¹

Once the construction contract has been awarded and clearing of the construction site has been 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 benching 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 cactus grab 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 would be transported by truck from the headframe bin to a rock disposal area. Once shafts have been excavated through the upper shale to the top of the water-bearing sandstone at elevation 1000, test holes 20 ft. deep would be drilled from each bench. The purpose of these holes is to probe for water prior to blasting a particular bench. Should water be encountered, additional holes would be drilled, packers installed and grouting from the shaft bottom would begin. It has been estimated that shaft sinking would be delayed about one month while traversing this water-bearing sandstone formation.

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 the forms through large diameter hoses.

Once the shaft has been excavated to its final depth, the sinking stage would be modified to permit its use as an equipping stage during installation of the permanent shaft equipment.

After the modification has been completed, the stage would be hoisted to the surface to begin shaft equipping. A summary of the hoisting systems is given in Appendix A. At this time, any water leaks in the lining would be grouted. This procedure, called drywalling, would reduce any water flows to an acceptable level.

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 - 1,513 ft. - in order to allow actual mine development to start at an earlier date than would be possible using conventional sinking techniques.

Both the equipment and method used for drilling 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 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 the 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 will 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.

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 ten-foot high sections consisting of an outer

shell of cold rolled mild steel strip plate of varying thickness from 3/8 in. to 1-in. and an inner lining of concrete 12 in. thick and varying in strength from 3500 psi to 6,000 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 will 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 will 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

In the excavated shafts the 12-in. thick lining is constructed of 3,500 psi poured-in-place concrete. Any water seeping through this lining would be collected in water rings and directed through vertical piping to the shaft bottom. During sinking, this water would be handled 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 the entire length. The liner consists of cold rolled mild steel plate from 3/8 in to 1 in. thick with an inner lining of 12 in. thick concrete, having a compressive strength of 3,500 psi to 6,000 psi. The installation of this liner has been covered in the Section 4.4.

4.6 Water Control Techniques

As previously mentioned, the principal difficulties to be overcome when excavating the shafts to the shale repository are: (1) the water flows expected to be encountered in the sandstones

above elevation 550; (2) the presence of water in the sandstone between 1000 and 1050; and (3) the groundwater in the sand and gravel overburden. In order to overcome these problems, the following techniques are to be used.

- a. Grouting. Prior to any shaft excavating, the interbedded sandstone above 550 would be grouted from the surface. Vertical holes would be drilled and cased through the overburden to the rock. These holes will continue to the top of the Upper Shale. It is proposed to inject chemical grout through these holes to the formation. It is necessary to grout these formations to prevent excessive water inflow to the shaft during excavating. The 50 ft. thick bed of sandstone below the 1,000 ft. elevation would be grouted during excavation. Test holes would be drilled from each bench at the same time as the blast holes are being drilled. Depending upon the amount of water intersected, additional holes would be drilled and grout injected.
- b. Overburden. The sand and gravel overlying the bedrock is reported as being water-bearing. Total depth of the overburden is 100 ft. with the water table at 60 ft. Construction of shaft collars in deep, water-bearing gravel can become difficult, time consuming and costly. There are several methods available, such as piling, drop shafts, caissons--open or pneumatic, forced drop shafts, cementation or grouting, well point pumping and freezing. In this study consideration was given to pumping and freezing techniques. Both of these methods require the bulk of the work to be carried out and completed prior to collar excavation with maintenance required during excavation.

4.7 Lateral Development From Shafts

Some lateral development from each shaft is required at the repository level. This work would be completed either during sinking of following sinking of a particular shaft. This lateral development is listed in Table 4-3.

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 4.3.2.1.

5.0 MINING AND WASTE PLACEMENT OPERATIONS IN SHALE¹

5.1 Design Criteria

The Mine Master Plans for the repository designs in shale for the 5-year retrievable cases in Cycles I, II, and III and the 25-year retrievable case in Cycle II are shown in Dwg. 25 in all sets, based on the estimated waste receiving rates as listed in Tables 5-4 through 5-9. The summary of the three Cycles for 5-year retrievability and Cycle II for 25-year retrievability are described, in Table 5-1. The following criteria were considered in the formulation of the Mine Master Plans:

- 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 be designed with consideration given 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 late 1985. This requirement affects excavation of the rooms, drilling of holes, and installation of canister sleeves. Subsequent storage rooms must be completed in time to permit receipt of predicted volumes 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 total repository area must not exceed 2000 acres (See Section 2.1.)

- o Shaft location is confined to 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

Figure 5 lists the room size employed for repository designs in the various Cycles studied as well as the pillar sizes and extraction ratios required to ensure mine stability.

In all mine layouts, four development corridors (entries) are needed. These main corridors, which are 26 ft. wide by 25 ft. high for Cycle II and 26 ft. wide by 20 ft. high for Cycles I and III on 86 ft. centers, serve the following functions: to emplace waste; to serve as a travelway for mining equipment, trucks and personnel; and to carry exhaust air from the mining operation. All of the supply air for mining is assumed to pass through the mining corridors while additional fresh air for placement operations would pass through the transporter corridor.

Storage rooms, 560 ft. long, have been grouped to form a panel. Access to storage rooms in a given panel is through a branch corridor, perpendicular to the main corridor. This layout permits flexibility and provides a number of working faces for the mining crew, allowing them to achieve maximum productivity. Rooms and corridors will have 1/2% slope to facilitate drainage. Smaller panels are anticipated to be developed in the earlier years for two reasons: to allow development panels to be completed in time for initial waste placement, and to match room development to canister receiving.

The ends of each room are connected to a 20 ft. wide by 12 ft. high branch exhaust corridor by a bottle-neck corridor which is 18 ft. wide by 12 ft. high by 30 ft. long. A ventilation regulator is located in the bottleneck corridor. The branch exhaust corridors would extend to meet the main exhaust corridors located on the perimeter of the repository. Since these corridors would

feed to the placement exhaust compartment of the upcast air shaft, they are designed to keep the exhaust air from the storage areas separate from the mine exhaust air which uses the main corridor system.

5.3. Mining Operations

In shale, conventional drilling and blasting techniques would be used to mine all corridors, rooms, service areas and ventilation corridors. A mining "cycle" for a production "unit" in shale would consist of drilling the drift face, loading the holes with explosives, charging and blasting, load hauling, scaling and roof bolting. The drilling would be performed by two-boom jumbos equipped with hydraulic drills. The machine is propelled by a 70 horsepower diesel engine and requires two 75 horsepower electric motors to drive the hydraulic drills and booms. A two man crew is used with each jumbo. The hydraulic drills are capable of drilling 2 in. diameter blast holes at a rate of 12 ft./min. However, when considering setup, moving and delays, the actual rate will range from 2.41 to 3.25 ft./min., depending on heading size.

A self-contained explosive loading machine with boom and basket would be used to load the charge into the blast holes pneumatically. A two man crew is required for this task.

Following detonation, the blasted rock will be loaded and hauled to the panel conveyor using 8-cubic-yard Load Haul Dump (LHD) machines. Two of these diesel powered machines will work in each heading.

Loose rock encountered on the ribs, face and roof will be taken down with a mechanical, diesel powered scaler and can be operated by one man. After the scaling operation, a modified two boom jumbo with a third boom carrying a man-basket would be used for installing roof bolts, channels and wire mesh. This machine would be comparable to the previously mentioned drill jumbo and would require a three man crew to operate.

Dimensions of rooms and corridors (entries) were dictated by the type of material being emplaced and the strength characteristics of the shale. The entries would be driven on two levels which are connected by a series of ramps. These levels are 1375 ft. and 1450 ft. below the ground surface. The 1375 ft. level would be used for emplacement of LLW and BWR, or IL-TRU and cladding waste material while PWR or HLW waste would be placed in the 1450 ft. level. The shale extraction ratios are shown in Fig. 5.

Since shale is likely to be considerably fractured, trenching as an alternative for canister storage is not feasible. waste canisters would be inserted into drilled holes in the floor of the storage room.

All canisters emplaced during the first five years of the storage activity would be retrievable during that five year period. After that, all rooms would be backfilled with the mine-run shale from the continuing room and development activity.

5.4 Initial Development

An assumption of five years between the start of construction of the first shaft and receipt 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 fifteen storage bins of total capacity of 8000 tons and a 440 ton surge bin) and conveyors, which would transport the material to the M&M Shaft, need to be installed to ensure efficient mining production. Last, at least one panel in each of the waste type areas is anticipated to be mined and ready to receive the incoming waste units by the end of 1985.

In order to begin mining as soon as possible, the first 1-1/2 years of mining operation would be through the Low-Level Waste

Shaft, since this shaft can be completed in about half the time as the M&M Shaft. During this period a temporary hoisting system with a capacity of about 2000 tons per day would be installed in the LLW Shaft and a shale handling system would be developed at the shaft base. When the M&M Shaft is completed, mining operations would gradually switch to this shaft, significantly increasing mining and hoisting capacities.

The following is a tentative schedule for the initial development of the repository. The schedule is roughly the same for all three 5-year cycles and the 25-year cycle. The start of construction is taken as time 0.0.

Year

0.0	All Shaft Construction Started.
1.5	LLW Shaft completed; temporary hoisting and shale handling system installed in LLW Shaft.
1.5-2.0	Mining initiated with one mining unit in operation; corridors leading from the LLW Shaft are mined; ventilation supplied via temporary duct in LLW Shaft; Ventilation Supply and Exhaust Shafts are completed.
2.0-3.0	Two mining units in operation; LLW corridors connected to main corridor system.
3.0	M&M and Canistered Waste Shafts completed; three mining units in operation.
3.0-4.0	Mining service area completed; corridors connected to Ventilation Supply and Exhaust Shafts; permanent hoisting and shale handling systems installed in M&M Shaft.
4.0-5.0	Four mining units in operation; panels to accommodate first two years of canister emplacement are completed.

5.5 Excavation of Storage Rooms

Following the initial development phase, panels for waste storage are anticipated to be developed to meet the expected rate of waste placement. A peak mining rate of approximately 3000 tons per day can be achieved during this phase. The mining production rates were computed assuming three working shifts per day and 250 working days per year based on a five day work week. If production

should fall behind schedule, one or more shifts could work seven days per week to make up the deficiency and then return to a normal work week.

Mining is assumed to be accomplished using large two-boom drill jumbos to drill holes for the explosives. The blasted material may be dumped from the load haul dumps (LHDs) into a feeder-breaker (crusher) at the inby end of the conveyor belt in each panel.

Extendible conveyors would be used in the panels to permit rapid advance. These conveyors, suspended from the room once they leave the feeder-breaker area, would discharge onto the main conveyor for transport to the central crusher located near the M&M Shaft. Estimated mining tonnages for shale are given in Table 5-3.

The panel numbers shown in each of the mine master plans signify the sequence in which the panels are mined for each storage area (see Dwg. 25 in all sets). 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 waste material would follow the drilling and in some cases may be done simultaneously with the drilling in the same panel (but not the same room) because of the time constraints. Dwg. 23 and 24 in all sets give the approximate time periods allotted to each operation for each panel. Note that waste placing and mining simultaneously in the same panel is never permitted.

As each room is completed it will be interconnected at the back to the previously completed room by the branch exhaust corridor. This will allow exhaust air to be drawn with fans through completed rooms and directed to the main exhaust corridor. In this manner the complete separation of mining and placing air would be ensured.

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 the 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 would be a period of two months to three years between the time of panel completion (holes drilled or sleeves installed) and placement of the waste canisters. An approximate time interval between the end of the mining of a panel and the beginning of canister placement in the same panel can also be ascertained from Dwgs. 23 and 24 in all sets. Labor requirements for the mining operation are given in Tables 1-2 through 1-4.

5.6 Drilling

Following excavation of the rooms, storage holes are drilled into the floor for all waste types except low-level which would be stacked in drums. Since the hole depth exceeds or nearly exceeds the room height, the drilling will be done in a multistage operation, using a two piece drill bit. The drillings are anticipated to be handled by front end loaders or large scooptrams which will carry the material to the main conveyor. The number and spacing of holes varies between waste types from one to two rows spaced at 6 ft. or 9 ft. as shown in Dwg. 27 in all sets. The indicated spacings are a function of the allowable local areal thermal loading and the heat per canister (Table 5-2). To ensure the integrity of the drilled holes, a spacing closer than 6 ft. is not permitted, even though the heat criteria mentioned above would allow closer spacings. When this situation occurs, close approximation of the allowable local areal thermal loading cannot occur.

The depth of the storage holes for Cycles I and III is 20 ft. and for Cycle II it is 25 ft. 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 twelve holes per 8-hour shift. Table 5-10 summarizes the drilled hole sizes and Tables 1-2 through 1-4 list the number of personnel assigned to the drilling operation.

5.7 Sleeve Emplacement

To ensure the integrity of the drilled hole in shale during the retrievable period, a 3/8 in. thick sleeve of mild steel is placed into the hole prior to waste emplacement. The sleeve's outside diameter is 16 in. for Cycles I and III, 18 in. for Cycle II PWR, and 14 in. for BWR. (See Table 5-10.) The length of the sleeves is approximately 18-1/2 ft. for wastes in Cycles I and III and approximately 23-1/2 ft. for wastes in Cycle II.

In the repository design, the sleeves are brought 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 would be used to support the concrete plug. A small amount of backfill may be required between sleeve and drilled hole to ensure that the canister would remain plumb during the placement process and throughout the retrieval period. It is anticipated that sleeve placement would be provided only during the retrievability period. The labor requirements for this operation are given in Tables 1-2 through 1-4 for each of the 5-year retrievable cases.

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 would thus act 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 off to the side for temporary surge storage. Thus the intermediate level would provide isolation between the unloading of the cage and the loading of the transporter. The transporter level would accommodate the final stage in the subsurface receiving operations before the waste is taken to a storage room. This level would provide two independent loading areas for the transport vehicles and vehicle queueing space. 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 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 are closed, the seal is removed and the transporter repositions the shielded chamber to an inclined position (to lower the center of gravity) for transport to the storage room. A cutaway 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 would slide open and a canister would be lowered down into the storage position. The hoist would then be disengaged and retracted. The second canister would be placed in a similar manner.

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.

It has been determined that even at the peak receiving rate, the surface facility is adequate to handle the incoming waste canisters. These canisters must also be properly received at the mine level, transported to the appropriate storage room, and stored at the peak rate. Accordingly, 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 design figure; 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.

The peak number of canister transporters required is a function of waste receipt schedule, transporter speed, the distance between the storage room and subsurface receiving station, the time required to load a transporter, and the time required to align the canister with the drilled hole (or trench). Because of the complex relationship among these factors, the maximum number of transporters required will not necessarily be proportional to peak year canister arrival rates. The peak transporter requirements are as follows: 4 in Cycle I; 5 in Cycle II - Five year retrievable; 4 in Cycle II - 25 year retrievable; and 4 in Cycle III.

In handling of low-level waste, a cage would lower pallets of drums to the subsurface facility. Forklift vehicles would be used to remove the pallets from the cage and place them on flatbed trucks to be transported to the storage rooms. At the storage rooms forklift-type vehicles would place the pallets in their 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 leaving a center aisle of 14 ft. wide. (See Dwg. 27 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

Once the retrievability period has been exceeded, backfilling can begin in the panels where waste placement has been completed. Approximately 58% of the materials for the rooms and panel access entry will be returned to these openings. This is based on a broken rock density of 90 pounds per cubic foot and 90% void filling in the rooms and entries.

Mined material would be carried from the working panel on a conveyor belt located in the panel branch corridor. The belt line would discharge into a splitter chute located at the junction of the branch and main corridors that will divert material onto one of two belts. One belt would carry the material to the shaft for surface disposal; the other would carry it to the current backfilling area.

Backfilling would begin at the rear of a panel and proceed toward the main corridors. The broken rock would be transported into the panel on an extendible conveyor belt that initially would extend the full length of the panel. The head pulley would be crawlermounted so that it may "back" itself out of the panel as backfilling progresses. Excess belting generated by this retreat would be drawn into an automatic belt storage unit. When the amount of belt in the unit reaches its storage capacity, the system would be shut down, a length of belt would be removed, and the system would be restarted. For the brief period of time that the belt is down, material would be diverted to the shaft.

The belt itself, when at its full panel length, would be made up of several segments, each piece being of a length equivalent to the maximum capacity of the belt storage unit. The pieces would be joined by mechanical hinge-and-pin type fasteners. This would allow the removal of the belt sections to be accomplished quickly and easily.

The individual rooms would be filled using similar extendible belts. The branch corridor belt would discharge at its head end onto two opposing belts carrying the material into the rooms themselves. The rooms would be filled in a retreating manner also, but several passes, or "lifts" would be made. That is, when one retreat has been made and the room partially filled, the conveyor would again be extended to the end of the room and the process repeated until the room is completely filled. While one conveyor belt is temporarily shut down for extension or removal to another room, the material would be diverted to the second belt. In addition, mechanical equipment would be used to bulldoze the material to the ribs and roof for maximum filling.

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 the surface storage to the extent possible. The excavation sequence would be reversed and material would be returned to the subterranean openings using the existing hoisting system in the Men and Material 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. 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 5.4.

6.0 VENTILATION SYSTEMS FOR FACILITIES IN SHALE

6.1 Subterranean Ventilation Systems

6.1.1 Ventilation Requirements and Criteria

The ventilation of the mining operations and of the subterranean waste storage rooms represents a complex 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 would 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);

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. Conceptual layout of the building is shown on 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, six centrifugal fans in parallel, each with a nominal capacity of 240,000 cfm, would supply a total of 1, 450,000 cfm of ventilation air underground. Two additional fans of the same capacity would be provided as back-up units to facilitate maintenance and/or repair without interruption of the air supply. The supply fans will would inlet vane control for efficient volume control capability. 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 the ventilation requirements of the mining operations such as drilling, blasting, mucking, drilling of waste placement holes, sleeve placement and backfilling. At the peak of the mining and placement activities this portion of the ventilation supply air will be approximately 1,100,000 cfm for all 5-year retrievable repository designs.

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. A conceptual layout of the subterranean ventilation system is shown on Dwg. 19.

All corridors and rooms would be mined by conventional drill and blast methods. During the mining operations, effective ventilation at the work places would be ensured by locating the exhaust tube inlet of the portable ventilating fan as close to the mining face as possible. The fan would exhaust the used air through the reinforced flexible tubing and discharge it through the adjacent already mined storage room into the panel vent drift of the periphery ventilation airway system. The panel vent drift would channel the air into the main corridor that serves exclusively as mine exhaust air corridor. Additional lengths of ducting would be added as required by the advancing mining operation.

Drilling of holes and placement of sleeves for the canistered waste would be ventilated by taking advantage of the fact that mining of the storage rooms is completed. In this scheme the supply air would flow past the work area through the entire room where the work is in progress, and would be will be exhausted through the adjacent unoccupied storage room and the panel vent drift into the mining air exhaust corridor.

The storage rooms would be backfilled after the 5-year retrievability period. Ventilation for backfilling would be provided the same way as it was provided during initial mining of the storage rooms. Fresh air would be sent down the branch corridor, into the room being backfilled and exhausted through the panel vent drift. From the panel vent drift the air is directed into the main exhaust corridor. Note that through redirection by a system of bulkheads, air from the mining operation will not interface with the 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 Section 5.1.1. For canistered waste placement operations the governing criterion is the air requirement for the diesel engine powered waste transporters, resulting in approximately 40,000 cfm fresh air per transporter. For low level waste placement operations, where forklift-type vehicles will be used to transport the palletized drums, ventilation would be determined by the minimum air velocity required in the occupied corridor or storage room. In a 26 ft. x 25 ft. low-level waste storage room this amounts to 32,500 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 canistered waste transporters operating simultaneously (including exhaust air from the subterranean waste receiving station).

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 Dwg. 19.) This way, the placement would always be done in a fresh air stream 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 will be continuously treated for contamination while the backfill and mining air will 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 underground ventilation system, would house the exhaust fans and the central filtering station. Schematic flow diagram of the exhaust air filtering system is shown on Dwy. 13.

Exhaust air from the placement compartment of the upcast 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 exclusively the mining operations 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% NBS efficiency prefilters and two sets of HEPA filters before discharge to the atmosphere through the exhaust stack. Since these additional filter-fan trains will 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 will be installed on each side of each filter bank and would 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. In final design of the airways, the system with the lowest overall cost is the goal.

For the ventilation airflows required the shale, the airway sizes selected in this preconceptual study resulted in the typical air velocities given in Table 15.

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 insure 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 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 and Low-Level 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. Ventilation flow rates would provide 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 5.1.5. If 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. In small and remotely located surface buildings, electrical cabinet heaters would be used.

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. 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

Schematic air flow diagram for the Canistered Waste Building is shown on Dwg. 6. The outside air would be drawn through pre-filters (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 pro-

vided 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 would 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 exhaust air flow rates from the primary and secondary confinement zones of the Canistered Waste Receiving Building are estimated to be 91,000 cfm from 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 would 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 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.

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 Receiving Facility 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 6-1.

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 standby power distribution system. Upon loss of normal power, the confinement zone ventilation supply system would automatically shut down and the exhaust fan will automatically operate at half speed. Exhaust air flow rates from the secondary confinement zones are estimated to be 8200 cfm for Fuel Cycle II and III repository designs, and 12,300 cfm for Fuel 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 backup capabilities, nor would it be linked to the standby 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 ten (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

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 season, 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 compactor 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 unit would also

serve the kitchen areas. 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.

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.

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 Repository

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.

Mine ventilation criteria and the method of ventilating the mining and placement operations is the same as the 5-year retrievable repository. The conceptual layout for the subterranean ventila-

tion system is the same as shown on Dwg. 19. 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 will be the same as described in Section 6.1.5 for 5-year retrievable repository designs.

SURFACE FACILITIES

FIG. 1

WASTE ISOLATION FACILITY

FIG. 2

CANISTERED WASTE BLDG. CUTAWAY PERSPECTIVE

FIG. 3

FIG. 4

WASTE RECEIVING OPERATIONS CUTAWAY PERSPECTIVE

Shale

CYCLE I

HLW: Extraction Ratio = 23%

ILW & CW: Extraction Ratio = 30%

CYCLE II

PWR: Extraction Ratio = 23%

BWR: Extraction Ratio = 30%

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 centimeters²)
 alpha emitting nuclides: 300 dis/min/dm^2

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

Table 1-2
Personnel Assignment Schedule
Shale - Cycle I

Year	Waste Storage Operation	Mining Operation *	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	8	-	-	-	72
1982	77	60	-	-	-	137
1983	85	244	-	-	-	329
1984	93	627	122	46	-	888
1985	629	330	155	29	-	1143
1986	647	448	211	29	-	1335
1987	666	305	143	29	-	1143
1988	700	312	147	29	-	1188
1989	754	300	141	-	-	1195
1990	775	314	148	-	33	1290
1991	810	315	148	-	34	1307
1992	810	305	143	-	32	1290
1993	810	342	161	-	36	1346
1994	896	469	221	-	50	1636
1995	976	517	243	-	55	1791
1996	1005	513	241	-	55	1814
1997	1108	380	179	-	40	1707
1998	1108	323	152	-	34	1617
1999	1125	82	39	-	122	1368
2000**	1247	-	39	-	105	1391
2001	220	-	-	-	87	307
2002	146	-	-	-	70	216
2003	110	-	-	-	52	162
2004	73	-	-	-	35	108
2005	37	-	-	-	17	54

*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 2000.

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
Shale - Cycle II

Year	Waste Storage Operation	Mining Operation*	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	10	-	-	-	74
1982	77	78	-	-	-	155
1983	85	225	-	-	-	310
1984	93	472	89	31	-	685
1985	457	336	188	10	-	991
1986	473	236	133	10	-	852
1987	486	232	130	9	-	857
1988	504	217	120	8	-	849
1989	523	217	122	-	-	862
1990	533	230	129	-	21	913
1991	551	230	129	-	21	931
1992	551	227	127	-	21	926
1993	551	227	127	-	21	926
1994	584	229	128	-	21	962
1995	617	233	131	-	22	1003
1996	627	453	254	-	42	1376
1997	670	295	166	-	27	1158
1998	670	399	224	-	37	1330
1999	676	434	243	-	40	1393
2000	717	419	235	-	39	1410
2001	717	460	257	-	43	1477
2002	744	372	209	-	35	1360
2003	770	329	185	-	31	1315
2004	774	456	256	-	42	1528
2005	810	259	145	-	24	1238
2006* *	810	-	145	-	132	1087
2007	220	-	-	-	132	352
2008	146	-	-	-	88	234
2009	110	-	-	-	66	176
2010	73	-	-	-	44	117
2011	37	-	-	-	22	59

*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 1-4
Personnel Assignment Schedule
Shale - Cycle III

Year	Waste Storage Operation	Mining Operation *	Drilling Operation	Sleeve Placement Operation	Backfill Operation	Total
1980	58	-	-	-	-	58
1981	64	8	-	-	-	72
1982	77	64	-	-	-	141
1983	85	263	-	-	-	348
1984	93	620	139	52	-	904
1985	460	306	139	30	-	935
1986	476	310	140	30	-	956
1987	490	326	147	30	-	993
1988	510	316	143	29	-	998
1989	537	383	174	-	-	1094
1990	549	323	146	-	32	1050
1991	569	317	144	-	31	1061
1992	569	302	137	-	30	1038
1993	569	235	106	-	23	933
1994	614	442	206	-	43	1305
1995	656	368	167	-	36	1227
1996	670	358	162	-	35	1225
1997	726	356	161	-	35	1278
1998	726	356	161	-	35	1278
1999	734	447	202	-	44	1427
2000	794	365	165	-	36	1360
2001* *	794	-	165	-	179	1138
2002	220	-	-	-	179	399
2003	146	-	-	-	119	265
2004	110	-	-	-	90	200
2005	73	-	-	-	60	133
2006	37	-	-	-	30	67

*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 2001.

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 - Shale

	Shale - Cycle I 5 Yr. Retrievable			Shale - Cycle II 5 Yr. Retrievable			Shale - Cycle II 25 Yr. Retrievable			Shale - 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
Admin. Bldg.	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
Whse. & Veh. Maint.	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
Gd. House RR Chk.	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
Laundry	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
M&M Bldg.	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
Oil Dpt. & Gen. Bldg.	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
Water Tower	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	4790	3780	423
Exhst. Vent. Bldg. #2	--	--	--	--	--	--	--	--	--	--	--	--
Supply Vent. Bldg.	2242	1701	10	2242	1701	10	2242	1701	10	2242	1701	10
Boiler Plant	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
HLW Bldg.	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
Radwaste Bldg.	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
Roadway Lighting	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
M&M Cage Hoist	675	675	675	675	675	675	675	675	675	675	675	675
Aux. M&M Hoist	136	136	--	136	136	--	136	136	--	136	136	--
M&M Skip Hoist	2078	2078	--	2078	2078	--	2078	2078	--	2078	2078	--
HLW Hoist. #1	1193	1193	--	1193	1193	--	1193	1193	--	1193	1193	--
HLW Hoist #2	1193	1193	--	1193	1193	--	1193	1193	--	1193	1193	--
LL-TRU Hoist	843	843	--	843	843	--	843	843	--	843	843	--
Undergrd. Serv., Transfer Sta., & Mine Lighting	3977	2076	194	3844	2014	188	3852	2021	189	3963	2079	195
Mining Substa. #1	2911	2184	--	2910	2183	--	2826	2120	--	2911	2183	--
Mining Substa. #2	2448	1836	--	2366	1775	--	2410	1808	--	2458	1844	--
Mining Substa. #3	2120	1590	--	2545	1909	--	2607	1955	--	2120	1590	--
TOTALS	30309	23031	2740	30518	23226	2734	30548	23249	2735	30305	23041	2741

TABLE 4-1

SHALESHAFT DIAMETERS (Feet)

DESIGNATION	<u>5-Year Retrievable</u>			<u>25-Year Retrievable</u>
	CYCLE I	CYCLE II	CYCLE III	CYCLE II
MEN & MATERIAL SHAFT	27	27	27	27
LOW-LEVEL WASTE SHAFT	10	10	10	10
CANISTERED WASTE SHAFT	14	14	14	14
VENTILATION SUPPLY SHAFT	26	26	26	24
VENTILATION EXHAUST SHAFT	26	26	26	24

Table 4-2

Basic Shaft Information for Shale

<u>Shaft Function</u>	<u>Diameter (Inside)</u>	<u>Depth</u>	<u>Excavation Method</u>
Men and Material	27 ft.	1662 ft.	Conventional
Ventilation Supply	26 ft.	1375 ft.	Conventional
Ventilation Exhaust	26 ft.	1450 ft.	Conventional
Canistered Waste	14 ft.	1513 ft.	Conventional
Low-Level Waste	10 ft.	1600 ft.	Bored

Table 4-3

Lateral Development from Shafts in Shale

<u>Shaft</u>	<u>Elevation</u>	<u>Description</u>
Men & Material	1450	Drift, 100' 1 x 20' h x 26' w
	1525	Drift, 100' 1 x 12' h x 20' w
	1662	Drift, 30' 1 x 12' h x 20' w
Ventilation Supply	1375	Two Drifts @ 90° to one another 30' 1 x 20' h x 26' w
Ventilation Exhaust	1450	Two Drifts @ 120° to one another 30' 1 x 20' h x 26' w
Low-Level Waste	1450	Drift, 150' 1 x 20' h x 26' w
Canistered Waste	1375	Transporter Room, approximately 19,000 cu. yds. Drift, 40' 1 x 20' h x 26' w
	1450	Transporter Room, approximately 19,000 cu. yds. Drift, 40' 1 x 20' h x 26' w

Table 5-1
SHALE REPOSITORY SUMMARY

Cycle (Date Filled)	Waste Type	Capacity (No. Con- tainers)	Room Length (feet)	Room Opening W x H (ft.)	Approx. ¹ Area (acres)	No. Rooms	Waste Units/ Room	Total No. Panels	No. Rooms per Panel/Panel Number	No. ² Rows	Long. Spacing ea. Row	Storage Configuration
I-Total Recycle (2000)	HLW (Glass)	47,472	560	18 x 20	620	516	92	7	14/P #1 72/P #2 86/P #3 to 7	1	6 ft.	Can. in Holes
	IL-TRU CW	159,340 31,928	560	26 x 20	762 153	693	276	10	30/P #1 78/P #2 to 9 39/P #10	3	6 ft.	Can. in Holes
	LL-TRU	278,208	560	26 x 20	69	42	6624	3	14			Palletized drums
II-Spent Unrepro- cessed Fuel (2006)	PWR	114,264	560	18 x 25	784	621	184	9	6/P #1 41/P #2 82/P #3 to 9	2	6 ft.	Can. in Holes
	BWR	166,704	560	26 x 25	804	604	276	10	19/P #1 51/P #2 70/P #3 to 9 44/P #10	3	6 ft.	Can. in Holes
	LLW	52,992	560	26 x 25	19	8	6624	1	8			Palletized drums
III- U Only Cycle (2001)	HLW (Glass)	51,612	560	18 x 20	680	561	92	8	28/P #1 82/P #2 to 7 41/P #8	1	6 ft.	Can. in Holes
	IL-TRU CW	154,553 34,231	560	26 x 20	744 165	684	276	11	28/P #1 46/P #2 74/P #3 to 9 46/P #10 to 11	3	6 ft.	Can. in Holes
	LL-TRU	52,992	560	26 x 20	19	8	6624	1	8			Palletized drums

Table 5-1 (Cont'd.)

REPOSITORY SUMMARY - SHALE
25-YEAR RETRIEVABLE CASE

<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>No.</u> ² <u>Rows</u>	<u>Long.</u> <u>Spacing</u> <u>ea. Row</u>	<u>Storage</u> <u>Configuration</u>
Cycle II (2003)	PWR	79,120	560	18 x 25	1038	860	92	11	10/P #1 76/P #2 86/P #3 to 11	1	6 ft.	Can. in Holes
	BWR	122,268	560	26 x 25	626	443	276	8	16/P #1 78/P #2 to 5 39/P #6 38/P #7 & 8	3	6 ft.	Can. in Holes
	LLW	46,368	560	26 x 25	12	7	6624	1	7			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 5-2

LOCAL AREAL THERMAL LOADINGSHALE

<u>Cycle</u>	<u>Waste Type</u>	<u>Average KW/can</u>	<u>Allow. Areal Thermal Loading</u>	<u>Design Areal Thermal Loading</u>
I	HLW	1.2	120	110
II	PWR	0.55	120	101
	BWR	0.18	120	50
II (25-Yr.)	PWR	0.55	55	50
	BWR	0.18	55	50
III	HLW + Pu (glass)	1.1	120	101

Table 5-3
REPOSITORY TONNAGE SUMMARY

	<u>Cycle</u>	<u>Tonnage Mined (x 10⁶)</u>	<u>Room Backfill Tonnage (x 10⁶)</u>	<u>Total Backfill Tonnage (x 10⁶)^a</u>	<u>Off-Site Removal Tonnage (x 10⁶)</u>	<u>On-Site Storage Tonnage (x 10⁶)^c</u>	<u>Backfill Tonnage Factor^b</u>
Shale	I	32	13	18	13	2	.579
	II	38	16	23	16	1	.591
	III	32	13	18	13	2	.579
	II (25-Yr.)	42	*	*	42	*	*

- 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 in-place 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 5-4
HIGH-LEVEL WASTE RECEIVING RATES^{a,e} (CYCLES I and III)

Year	Glass Waste Canisters		Calcine Waste Canisters	
	Annual	Accumulated	Annual	Accumulated
1985 ^d	215	215	240	240
1986	859	1073	966	1206
1987	1141	2214	1283	2490
1988	1293	3507	1454	3943
1989	1461	4968	1643	5586
1990	1577	6545	1773	7359
1991	2126	8671	2389	9749
1992	2410	11081	2709	12458
1993	2702	13783	3038	15496
1994	3089	16872	3472	18968
1995	3640	20512	4090	23058
1996	3841	24353	4317	27375
1997	4368	28721	4909	32284
1998	4881	33602	5486	37770
1999	5434	39037	6109	43878
2000	6004	45040	6748	50626
2001	6543	51583	7355	57981
2002	7119	58702	8001	65982
2003	7698	66400	8652	74634
2004	8293	74692	9322	83956
2005	8888	83580	9989	93945
2006	9478	93058	10654	104599
2007	10033	103091	11277	115876
2008	10558	113650	11867	127743
2009	11069	124719	12441	140184
2010	11564	136283	12997	153181
2011	12012	148295	13498	166679
2012	11923	160218	13403	180082
2013	11809	172027	13274	193356
2014	11688	183715	13137	206493
2015	11599	195314	13036	219529
2016	11382	206696	12791	232320
2017	11209	217905	12600	244920
2018	11039	228944	12409	257329
2019	10862	239806	12208	269537
2020	10745	250551	12077	281614
2021	10565	261116	11874	293488
2022	10206	271322	11471	304959
2023	10197	281519	11459	316418
2024	10206	291725	11471	327889
2025	9784	301509	10995	338884

^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 7.0 ft³/MTU and canister volume of 6.28 ft³ (0.178m³).

^cAssuming waste density of 3.5 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 with Pu in HLW.

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	34328
1992	11629	54438	11250	45578
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

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 5-7

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 5-8

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 5-9

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) waste.

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

TABLE 5-10

DRILLED HOLE SIZESSHALE

	<u>Canister Size O.D.</u>	<u>Sleeve O.D.</u>	<u>Hole Size w/ Sleeve</u>	<u>Hole Size w/o Sleeve</u>
Cycle I - 5 Yr. Ret. - HLW,IL-TRU,CW	12-3/4"	16"	22"	20"
Cycle II - 5 Yr. Ret. - PWR	14"	18"	24"	20"
BWR	10-3/4"	14"	20"	18"
Cycle II - 25 Yr. Ret. - PWR	14"	18"	24"	20"
BWR	10-3/4"	14"	20"	18"
Cycle III - 5 Yr. Ret. HLW,IL-TRU,CW	12-3/4"	16"	22"	20"

NOTES:

1. Drilled holes are used for canister storage.
2. For overpacked canisters assume hole and sleeve sizes 2" larger. Assume that overpacked canisters will represent 2% of total number of canisters in each room.

Table 6-1

TYPICAL SUBSURFACE VENTILATING FAN SPECIFICATIONS

TYPE	Capacity (cfm) <u>per fan</u>	Est. Total Pressure <u>(inches of water)</u>	Motor (HP)
Main Supply Fans	240,000	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* (fpm)
Shale (5-Yr.):				
Fuel Cycle I	1,250,000	250,000	1,500,000	26 ft/2970
Cycles II & III	1,250,000	250,000	1,500,000	26 ft/2970
Shale (25-Yr.):				
Fuel Cycle II	1,200,000	250,000	1,450,000	24 ft/3340

* Average velocity for mining and placement compartments.

TABLE 6-3

SUBSURFACE AIR VELOCITIES

<u>Type of Airway</u>	<u>Air Velocity (fpm)</u>
Ventilation Shafts (Concrete lined, smooth surface)	2970-3340
Main Supply Air Corridors	
Cycles I & III	450-500
Cycle II, 5 & 25-yr. retrievable	400-450
Branch Corridors, carrying air for:	
Drill/blast & mucking	300-600
Storage hole drilling	150-200
Backfilling	100
Storage Rooms, with	
Mining in progress	50-300
Waste placement in progress	Min. 50
Mining Air Exhaust Corridor	750-1000
Placement Air Exhaust Airways	
Branch airways	150-300
Main airways	250-500

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 Criteria</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.

**For a definition of Confinement Zone, see Section 6.2.1.2.

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	
			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	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	-

*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 five 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.: 10'-0"
No. Ropes: 4
Rope Size: 1 3/16" L.C.
RMS H.P.: 2,465 (S.C.)
RMS H.P.: 2,027 (F.V.)

S.C. - Self-Cooled
F.V. - Forced Ventilation
L.C. - Locked Coil
F.S. - Flattened Strand

b. Cage Hoist

No: 1
Type: Friction
Mounting: Tower
Wheel Dia.: 10'-0"
No. Ropes: 4
Rope Size: 1 3/16" L.C.
RMS H.P.: 800 (S.C.)

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

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. I.H.T.
RMS H.P.: 1,000 (S.C.)

3. Canistered Waste Shaft

No: 2
Type: Friction
Mounting: Tower
Wheel Dia.: 14'-0"
No. Head Ropes: 6
Head Rope Size: 1 7/8" L.C.
No. Tail Ropes: None
RMS H.P.: 1,415 (F.V.)

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 a ground mounted single drum hoist would be roped with two 1 1/2 inch flattened strand cables. A 9.5-ton capacity skip with a removable cage would be hoisted in balance with a counterweight. Hoisting speed is 1200 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, CW, or PWR/BWR canisters. 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 interior liner. The cage has an estimated maximum 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 half. 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 buntions 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. The 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 9,500 TPD in two 13-ton capacity skips operating in balance. The hoist is a friction type with a wheel diameter of 10 ft. and a hoisting speed of 1,800 FPM.

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

1. Capacity to sling 26-ton load.
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 10 ft. and is equipped with four 1 3/16 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

For the purpose of this study, five shafts have been designed to accommodate the excavation of an underground repository in shale 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 A-2.

Table A-1 Excavated Shafts - Time in Weeks

Item	27'Ø M&M	26'Ø SuA	26'Ø ExA	14'Ø Can. Waste
1. Contractor's Mobilization	6	6	6	6
2. Pregrout to 550 Elevation	26	26	26	24
3. Collar and Headframe	52	37	37	49
4. Shaft Sinking, Lateral Development, Equipping	40	26	29	31
5. Grout @ 100-1050 Level	3	3	3	3
6. Excavate Transporter Stn.				26
7. Install Permanent Equipment, Misc. Delays	17	15	21	19
TOTAL	144	113	122	158

Table A-2 Bored Shaft - Time in Weeks

Item	10'Ø LLW
1. Contractor's Mobilization	6
2. Contractor's Site Preparation	8
3. Shaft Drilling, Lining, Grouting	37
4. Construct Headframe, Equipping	18
5. Excavate 1425 Station	16
6. Miscellaneous Delays	4
TOTAL	89

APPENDIX B

JOB CLASSIFICATION BREAKDOWN SUMMARY

SHALE CYCLE II

	<u>Symbol</u>	<u>Number</u>
Supervisory and Clerical	A	102
Administrative and Management	B	179
Professionals	C	24
Skilled Labor	D	1,018
Miners	E	39
Semi-skilled Labor	F	273
Technicians	T	31
		<u>1,666</u>

The above figures correspond to the peak average daily man-shift requirements occurring in the year 2004 for the Shale 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 classification 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 charge loading crews, blasting crews, and jumbo operators. 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 2004 with the values shown in the tables 1-2, 1-3, and 1-4 of the Shale Technical Report.

JOB CLASSIFICATION BREAKDOWN

SHALE CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job⁺ Classifi</u>	<u>io</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	15	D	
Transporter Operators	25	D	
Transporter Maintenance	10	D	
Room Laborers	15	F	
Crusher Crew	8	F	
Maintenance Crews	8	D	
Above Ground Storage			
a) High Level Waste Bldg.			
Cask Washdown Crews	17	F	
Bay Crane Operators	12	D	
Bay Laborers	23	F	
Bay Inspectors and Monitors	16	D	
Transfer Cell Monitors	9	D	
Transfer Cell Operators	48	D	
Crane Operators	12	D	
Hoist Operators	12	D	
Lab Personnel	10	T	
Mechanical and Electrical Services	12	D	
Supervisors and Clerical	15	A	
b) Low Level Waste Bldg.			
Crane Operator	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	27	B	
d) Railroad Operations			
Operations Personnel	26	D	
Equipment Maintenance	20	D	

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

JOB CLASSIFICATION BREAKDOWN
SHALE CYCLE II

	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
e) Shipment Inspections Handling and Warehouse Operations	14	F
f) Liquid Rad Waste	3	D
Crane Operators	5	T
Lab Personnel		
Mechanical and Electrical Service	2	D
Supervisors and Clerical	5	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
Buildings	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	22	D
Administration and Management	<u>125</u>	B
Total of Waste Storage Operation	774	

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

JOB CLASSIFICATION BREAKDOWN

SHALE CYCLE II

II - Mining Operation

<u>Section</u>	<u>Type</u>	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
Mining @ Face	Foreman	14	E
	Jumbo Operators	16	E
	Blasters	9	E
	Helpers	4	F
	Roof Bolting and Scaling	27	D
	Loader Operators	16	D
	Dozer Operators	2	D
	General Labor	14	F
Underground Haulage	Conveyor Attendants	26	D
	Truck Drivers	7	D
	Loader Operators	13	D
Shaft Hoisting	Hoistmen	3	D
	Skip Tenders	6	D
	Cage Tenders	3	D
	Deckmen	4	D
Surface Disposal	Equipment Operators	34	D
Support	Jumbo Maintenance	14	D
	Blasting Maintenance Crew	20	D
	Truck and Loader		
	Maintenance	12	D
	Dozer Maintenance	2	D
	Ventilation Maintenance		
	and Repair	27	D
	Sealing and Bolting		
	Maintenance	14	D
	Electricians	28	D
	Crusher Operators		
	and Maintenance	17	D
	Roadway Maintenance	11	D
	Hoist Maintenance	13	D
	Utility Maintenance	10	D
	General Labor	39	F
	Supervisors and Clerks	51	A
Total of Mining Operation		456	

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

JOB CLASSIFICATION BREAKDOWN

SHALE CYCLE II

III - Drilling Operation

<u>Section</u>	<u>Type</u>	<u>Man-Shifts Per Day</u>	<u>Job* Classification</u>
Drilling	Drillers	47	D
	Helpers	46	F
	Loader Operators	46	D
	Machine Maintenance and Repair	<u>117</u>	D
	Total of Drilling Operation	256	

IV - Backfill Operation

Backfill	Conveyor Tenders	24	D
	Loader Operators	12	D
	General Maintenance	<u>6</u>	F
	Total of Backfill Operation	42	

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

JOB CLASSIFICATION BREAKDOWN

	<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	D
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

	<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"