CONCEPTUAL DESIGN CRITERIA
for
FACILITIES FOR GEOLOGIC DISPOSAL OF
RADIOACTIVE WASTES IN SALT FORMATIONS

Prepared by
UCC-ND ENGINEERING

January 1977

UNION
CARBIDE

NUCLEAR DIVISION
OAK RIDGE, TENNESSEE

prepared for the U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under U.S. GOVERNMENT Contract W-7405 eng 26

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Issue Date: Jan. 5, 1977

Document Number X-OE-17
Y/OWI/TM-9

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1. GENERAL CRITERIA

1.1 Introduction

In February 1976 the Energy Research and Development Administration established the National Waste Terminal Storage (NWTS) program, which has as its objectives:

1. to provide terminal storage facilities for commercial radioactive waste in various geological formations at multiple sites in the United States in a time frame that assures nuclear power is a viable energy option,
2. to provide the capability to safely dispose of commercial radioactive waste shipped to ERDA as required by Title 10, Code of Federal Regulations, Part 50 (10-CFR-50), Appendix F, and any other waste which must be delivered to a federal repository for terminal storage.

Regulations in 10-CFR-50 pertain to licensing of production and utilization facilities, and Appendix F refers to siting of reprocessing plants and related waste management facilities. In brief, Appendix F requires that: (1) a fuel reprocessing plant's inventory of high-level liquid radioactive wastes be limited to that produced in the prior five years, and (2) high-level liquid radioactive waste be converted to a dry solid and placed in a sealed container prior to transfer to a federal repository no later than ten years following separation of fission products from irradiated fuel.

Additionally, requirements for shipment of waste to a federal repository may be included in changes to 10-CFR-20, "Standards for Protection Against Radiation." Changes currently proposed relate to transuranic (TRU) waste disposal and will require that waste with contamination levels as low as 10 nCi of TRU elements per gram of waste must be transferred to ERDA for storage in a federal repository as soon as practicable, but within five years after its generation.

At present there are no federal repositories in the United States, and there are no commercial reprocessing plants in operation. In fact, high-level radioactive waste has not been generated commercially in the U.S., with the exception of a small amount generated at the Nuclear Fuel Services Plant at West Valley, New York, during the years 1966-1972. However, decisions on fuel recycle authorization are due and, if approved, will require that waste storage and disposal facilities be available in a time frame to accommodate the commercial high-level wastes that are anticipated. In the event that recycle is not approved and the nuclear fuel cycle is left incomplete, it will still be necessary to have waste storage facilities available at the earliest possible date for disposition of spent fuel elements and other containerized waste directed to a federal repository. Therefore, to implement the NWTS program charter, a terminal waste storage facility with the earliest possible start-up date must be provided. This initial step calls for geologic disposal in rock salt; this document provides criteria for the conceptual design of these initial facilities.

1.2 General Description

This project encompasses the conceptual design of a facility for the long-term geologic storage and eventual disposal of commercial radioactive wastes. Although a specific site has not yet been selected, the terminal waste storage plant will be located to utilize, as the geologic storage medium, rock salt deposits that are typically located at depths of 800 to 4000 ft below the surface. Commercial radioactive wastes to be accepted for storage will include high-level waste (HLW), cladding hulls, intermediate-level transuranic

waste (ILW), and low-level transuranic waste (LLW). In addition, provisions should be made for handling unprocessed spent reactor fuel elements. The plant will consist of facilities designed to receive these wastes, prepare them for storage, and store them in a retrievable configuration.

The surface facilities will provide for the receipt and unloading of waste shipping containers at frequent intervals; the transfer of the waste containers to inspection facilities, where, if necessary, the containers will be decontaminated and overpacked; and the preparation of the waste for descent to the mine level. There will be two basic process lines developed to handle the wastes in this manner. The distinction will lie in the type of waste being handled; that is, wastes which require shielding and hot-cell facilities and wastes which do not. In addition to these surface process facilities, surface support installations will be necessary, such as an administration building, maintenance and warehouse areas, and utility systems. There will be transfer shafts and hoisting arrangements for transporting wastes, materials, and mine operating personnel to and from the mine level.

The underground facilities and equipment will receive the wastes, transport them to the proper storage sites, and unload the containers and place them in retrievable storage. The underground mine facilities will also be dual in nature, in that separate mine shafts, areas, and methods will be employed for wastes requiring shielded and nonshielded handling. Furthermore, the mine should be expandable from initially limited proportions to an area large enough to accommodate the waste volumes anticipated from the nuclear industry into the 21st century.

The initial-phase facilities are to be designed so that they will comply with all statutory, regulatory, and licensing requirements that may exist. Present planning calls for licensing of these facilities by the Nuclear Regulatory Commission (NRC). At some future date, cessation of operations performed solely to allow the retrievability option may be allowed. The plant will be designed to protect the public and operating personnel from radiation and/or contamination hazards during normal operations and under design-basis accident situations. In addition, the surface facilities will maintain their integrity under flood, earthquake, and tornado design conditions.

Radioactive wastes produced by the facilities will be processed, handled, and stored on site. The effluents released will be controlled in such a manner as to result in a substantial reduction from current practice. To achieve this objective, controlled-environment areas having low inleakage rates will be required, and recirculation of the controlled atmospheres may be provided in lieu of once-through systems.

Reliability and maintainability of the facilities will be a prime consideration.

1.3 Method of Accomplishment and Responsibilities

1.3.1 Energy Research and Development Administration

ERDA will furnish overall project coordination, will review and approve all required documents, will administer all prime contracts, and will direct and administer all aspects of the project, including specific approval of work assignments and approval of work performed.

1.3.2 Union Carbide Corporation, Nuclear Division

UCC-ND, working under prime contract to ERDA, will provide criteria, furnish comments to ERDA on the conceptual documents, and provide technical support. Programmatic criteria will be provided by UCC-ND's Office of Waste Isolation (OWI), with technical support to OWI provided by UCC-ND's Engineering Division.

In addition, UCC—ND will assist the architect—engineer in preparing the following sections of the Conceptual Design Report (CDR):

- Introduction
- Brief Physical Description of Project
- Project Purpose and Justification
- Principal Safety, Fire, and Health Hazards
- Environmental Impact
- Quality Assurance
- Project Schedule
- Proposed Method of Accomplishment
- Summary Cost Estimate

UCC—ND will review and recommend approval of all documents required of the architect—engineer.

1.3.3 Architect—Engineer

The architect—engineer, working under prime contract to ERDA, will be responsible for preparing the conceptual design report, drawings, schedules, and cost estimates for the terminal waste storage facility.

1.4 Conceptual Design Scope

The effort of the architect—engineer on the conceptual design will begin in January 1977 and will be completed by January 1979. The result of this effort will be an approved CDR describing the project by means of flowsheets, drawings, narrative descriptions, and outline specifications. The CDR will also include a cost estimate, prepared in accordance with procedures to be supplied by ERDA, and a schedule for construction.

Interim documentation will be submitted to the ERDA Engineering Division and to UCC—ND for review. In addition to standard ERDA reporting requirements, interim documentation will include:

1. a CDR outline,
2. a quality assurance plan for subsequent design and construction activities (see Sect. 1.8) which will be submitted at the 75% complete conceptual design milestone,
3. draft sections of the CDR on which UCC ND will assist as outlined in Sect. 1.3.2,
4. project cost data which should include projected operating costs in addition to construction data.
5. a preliminary draft of the CDR, which is to be issued for review and approval by October 1, 1978 (the CDR would be issued and approved no later than December 1, 1978).

1.5 Design Basis Information

Certain assumptions concerning waste types, packaging, and shipping have been made in support of the criteria specified in this document. These assumptions were selected as the current best choices of several alternatives in order to direct the immediate design effort toward a single facility definition. Other alternatives will be studied by UCC—ND or by the architect—engineer in parallel, and as more definitive results become available and the conceptual design evolves, the current criteria may be amended.

1.5.1 Waste Types

The terminal waste storage plant will be designed to accept commercial high-level waste, cladding hulls, intermediate-level transuranic waste, and low-level transuranic waste, as defined in the Appendix, in

addition to light-water reactor (LWR) spent fuel assemblies. Furthermore, storage of plutonium oxide, fission product iodine, and tritium may be eventual considerations in the facility design.

1.5.2 Waste Packaging and Shipping

The commercial high-level waste will be packaged and shipped to the plant as a dry solid that is chemically, thermally, and radiolytically stable. Approximately 6.3 ft^3 of waste will be encapsulated in a sealed cylindrical canister that is constructed of type 304L stainless steel and has a 12-in. inside diameter and an overall length of 10 ft. An 11-ft-long overpack, with 14-in. outside diameter and $\frac{1}{4}$ -in. wall thickness, may be employed to encase the canisters. The maximum total weight of the canister, overpack, and contents will be 3000 lb. Both the canister and overpack will be equipped with a standardized connector pin for lifting and handling. The thermal power of any single waste canister will not exceed 5 kW when received at the plant. Maximum neutron dose rates will be: surface, 7 rem/hr; 10 ft from centerline, 0.35 rem/hr. Maximum gamma dose rates will be: surface, 1.5×10^5 rem/hr; 10 ft from center line, 8.0×10^3 rem/hr. A conceptual high-level waste canister configuration is shown in Fig. 2.¹ Transportation of the high-level waste canisters is discussed in ERDA-76-43, "Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle" (commonly referred to as the Technical Alternatives Document, TAD). The postulated rail shipping cask has an insert diameter of 60 in. and can accommodate nine canisters. The shield will be about 10 ft in diameter, 16 ft long, and will not weigh more than 110 tons.

The cladding hulls will be packaged, shipped, and handled in much the same manner as the commercial high-level waste. For the purposes of initiating the conceptual design, it will be assumed that the waste will be packaged in a stainless steel canister externally identical to the high-level canister. Differences may be allowed in contained waste volume and canister wall thickness. As parallel studies become conclusive, these criteria may change. The maximum thermal power of any single canister will be 55 W. Neutron dose rates will be negligible. Maximum gamma dose rates will be: surface, 1.3×10^3 rem/hr; 10 ft from centerline, 650 rem/hr. Maximum canister weight will be 3000 lb.

The intermediate-level transuranic waste will also be packaged, shipped, and handled in much the same manner as the high-level waste. For the purposes of initiating the conceptual design, it will be assumed that the waste will be packaged in a stainless steel canister identical to the high-level canister except perhaps for waste volume and canister wall thickness. Since only a small amount of shielding is required with these wastes, alternate packaging may be explored as system design or parallel studies dictate. Neutron dose rates will be negligible. Maximum gamma dose rates will be: surface, 1 rem/hr; 10 ft from centerline, 0.05 rem/hr.

The commercial low-level transuranic wastes will be contained in carbon steel drums of nominal 55-gal capacity. These waste drums will be shipped to the plant by truck and/or rail, utilizing returnable cargo containers. It will be assumed that waste drums shipped by truck will utilize $8 \times 8 \times 20$ ft long "Super Tiger" type B cargo containers with a maximum weight of 44,300 lb when filled with 42 drums. Rail shipments will utilize the AMTX-600 railcar or conventional rail flatcars. The AMTX-6000 will carry two "Super Tigers"; the conventional railcar can handle three. The low-level waste drums will be removed from the shipping containers, palletized, and transferred to the low-level mine for storage. Any damaged drums will be overpacked in nominal 83-gal carbon steel drums.

1. All figures cited in the text are located in the Appendix.

Commercial spent fuel assemblies are assumed to be packaged, shipped, and handled in much the same manner as the commercial high-level waste. For the purposes of initiating the conceptual design, it will be assumed that the spent fuel assembly will be the reference LWR fuel assembly outlined in TAD and summarized as follows:

Properties of a Reference LWR Fuel Assembly Cooled for 120 Days

Assumed overall length	4.470 m (boiling-water reactor – BWR)
Assumed cross section	21.4 cm × 21.4 cm (pressurized water reactor – PWR)
Assembly total weight	454 kg
Uranium/assembly	311 kg
Total radioactivity	1.9×10^6 Ci
Fission product activity	1.7×10^6 Ci
Transuranic content	5.5 kg
Transuranic activity	1.1×10^5 Ci
Neutron source strength	1.3×10^9 neutrons/sec
Total thermal power	8.4 kW
Total gamma power	1.4 kW
Exposure	25,000 MWd/MTU (metric ton of U)
Average specific power	35 MW/MTU

Additionally, consideration in the facility design may eventually be given to receiving plutonium oxide, fission product iodine, and tritium. Preliminary criteria for these wastes are supplied by the information given in TAD, Vol. 3, Sect. 22.

Shipments of radioactive wastes will conform to applicable Department of Transportation (DOT) and NRC regulations for transport of radioactive materials. Reference is made to TAD, Vol. 5, Appendix E.

1.5.3 Facility Capacity Design

The surface and handling facilities will be designed to accommodate the waste quantities projected through the year 2005, as summarized in Tables 1–5 in the Appendix. The mine storage will be designed for an initial capacity of one-half the quantities available through 1990, with a mine master plan developed by the architect-engineer to handle the quantities projected through the year 2005. This is also summarized in Tables 1–5 in the Appendix. These tables are based on the Blomeke and Kee² projections. The plant will initially be assumed to operate on a schedule of one shift per day, five days per week. Shipments received on weekends will not be unloaded until the next working day, and this will be reflected in the design of the receiving facilities. The full-scale repository will be assumed to operate with three shifts per day, five days per week.

1.6 Health, Safety, Security, and Accident Conditions

1.6.1 Radiological Safety and Confinement

Radiation control and monitoring systems will meet the requirements of Regulatory Guides 3.18, 3.20, and 3.24; ERDA Manual Appendix 6301, Part II, Sect. I; Title 10, Part 20, of the Code of Federal Regulations; and Appendix P of Title 10, Part 50, of the Code of Federal Regulations. The policy of these

2. J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated," *Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle*, Denver, Colorado, July 11–16, 1976, CONF 76-0701, pp. 96–117.

standards is to protect the general public, operating personnel, and property; this means that operations will be conducted in a manner to assure that radiation exposures to individuals and population groups are limited to the lowest levels technically and economically feasible. The following are supplementary criteria for use in design of the facilities.

1.6.1.1 Protection of repository personnel. Radiation shields and contamination limits, together with the extent of occupancy of the affected zones, will be selected such that the weekly averaged dose or dose commitment to operating personnel will not exceed that of the radiation protection standards prorated for one week of exposure. For continuously occupied zones, these limits are considered to correspond to a penetrating radiation dose rate no greater than 0.25 millirem/hr and levels of transferable surface contamination, other than uranium or thorium, no greater than $20 \text{ dis min}^{-1} \text{ cm}^{-2}$ from alpha radiation and $200 \text{ dis min}^{-1} \text{ cm}^{-2}$ from beta-gamma radiation. The levels of uranium or thorium can exceed these by a factor of 10. Concrete shields for normally occupied work areas such as the operating gallery of a high-level transfer cell will be designed to limit the basic dose rate to 0.25 millirem/hr to provide contingency for shield penetrations and dose accumulation in zones of high radiation.

Posted, controlled access radiation zones will be established in those areas (such as the high-level cask receiving and decontamination areas) in which the weekly averaged penetrating radiation dose rate is greater than 1 millirem/hr.

Automatic alarms and interlocks will be provided in all areas where the potential for exposure to high radiation levels exists, to warn personnel and prevent them from entering these areas.

Posted, controlled-access contamination zones will be established in those areas which have significant potential for direct-reading surface contamination in excess of $300 \text{ dis min}^{-1} \text{ cm}^{-2}$ of alpha radiation, $10,000 \text{ dis min}^{-1} \text{ cm}^{-2}$ of beta-gamma radiation, or transferable surface contamination in excess of 10% of these values. Surfaces in such areas must be easily decontaminable. Contamination control will be accomplished through the use of physical confinement barriers and by the maintenance of air flow in the direction of increasing contamination potential. A face velocity of air of at least 150 ft/min will be provided to isolate zones of potential contamination from their surroundings. Air will be exhausted from zones of highest potential contamination through high-efficiency particulate air (HEPA) filters. Decontamination systems will be provided in the above areas.

Regulated zones with physical confinement barriers will be provided as a buffer between contamination zones and the environment. Such zones will consist primarily of air locks and change rooms for the passage of personnel and materials.

1.6.1.2 Protection of the public. The public will be protected from radiation exposure through the control of unauthorized access to the plant facilities and the control of plant effluents.

Personnel and vehicular access to zones of possible radiation or contamination hazard within the plant site will be limited by exclusion fencing.

There will be no discharge of radioactive materials to the sanitary sewer system. Solid wastes generated within the repository will be packaged and buried in the mine. Contaminated wastes will be recycled through an evaporator and ion exchange treatment system. The bottoms from the evaporator and the spent ion exchange resin will be converted to an inert solid, which will be packaged and stored in the mine. Distillate from the evaporator and other waste water will be processed for reuse or evaporated to the atmosphere.

Releases of airborne radioactive materials from the plant will be maintained at the lowest practical levels and well below applicable standards by:

1. providing decontamination operations to maintain surfaces in contact with ventilation streams as free of transferable contamination as practical,

2. passing all air from zones of potential contamination through HEPA filters which are suitably equipped to permit periodic in situ testing and replacement without compromising the integrity of the confinement system.

Confinement barriers (including critical structures and ventilation systems) and personnel protection and instrument systems will be designed, tested, routinely inspected, and maintained to ensure that confinement criteria and radiation safety are maintained during and following exposure to any credible internal and external forces.

1.6.2 Mine Safety

Minimum mine and tunnel safety standards and guidelines will be those in the Federal Health and Safety Standards, "Metal and Non-Metallic Underground Mines," 30-CFR-57, and Mining Enforcement and Safety Administration (MESA) Standards, including applicable Tunnel Safety Orders and Mine Safety Orders, Administrative Code, State of California.

1.6.3 Industrial Safety

The plant will conform to the industrial safety requirements of ERDA Manual 6301, General Design Criteria; American National Standards Institute (ANSI) Standards for Safety; 29-CFR-1926, Safety and Health Regulations for Construction; 29-CFR-1910, Occupational Safety and Health Standards; National Fire Protection Association Codes; and EM 385-1-1, Corps of Engineers General Safety Requirements, without limitation.

1.6.4 Fire Safety

Fire protection will be provided in accordance with Regulatory Guide 3.16. The administrative and surface operating areas will be equipped with a wet-sprinkler fire protection system in accordance with Sects. 2.1, 2.2, 2.3, and 2.4 of UCC-ND Y-EF-538, "General Design Criteria for UCC-ND Engineering Projects." The use of HALON 1301 will be investigated for fire protection in the operating galleries control rooms, and cell support bays. The adequacy of the inert cell atmospheres will be evaluated for fire protection capability, and supplementary fire protection systems will be provided in the cells as necessary.

1.6.5 Seismic Design Requirements

At present there are no specific criteria available for determining the seismic design basis for waste storage facilities. However, several documents contain requirements for similar or related nuclear facilities, and these will be used as guidelines, bearing in mind that unrealistic precedents should not be established in the conceptual design that would place a burden on subsequent design and construction. Geologic and seismic investigation of the site will be made in accordance with the requirements of 10-CFR-100, Appendix A, when a specific site is selected; the selection of a site will probably not take place during the conceptual design.

All structures, systems, and equipment of the plant will be classified for seismic design purposes as Seismic Category I or non-Category I items. This seismic design classification is intended to parallel and utilize existing standards and guides where possible. The seismic design classification for Seismic Category I items will be in accordance with Regulatory Guide 3.14, except that where specific mention in Regulatory Guide 3.14 is made of plutonium the intent here is to include *all* radioactive waste materials. For purposes

of initiating the conceptual design effort, Seismic Category I items will be analyzed for earthquake loading in accordance with the uniform Building Code for Zone I requirements.

1.6.6 Tornado Design Requirements

At present there are no specific criteria available for determining the tornado design basis for the facilities. However, several documents contain requirements for similar or related nuclear facilities and these will be used as guidelines for tornado design. As in the case with the seismic design requirements (Sect. 1.6.5), it is imperative that unrealistic precedents not be established in the conceptual design that would in turn place a burden on all subsequent design and construction.

The overall design will incorporate all practical features which minimize the adverse effects resulting from the design basis tornado specified below. All effects of transient pressure drop are to be carefully analyzed to assure integrity of the design for structures, confinement systems, and off-gas cleaning components and to minimize the release of airborne radioactive materials to the environment. All items classified as Category I in accordance with Regulatory Guide 3.14 will be designed to maintain functional integrity during the design basis tornado.

The following design conditions will be used for the design basis tornado in accordance with Regulatory Guide 1.76:

1. 290 mph tangential velocity,
2. 70 mph transverse velocity,
3. 3 psi average transient pressure drop at 2 psi/sec,
4. 150 ft radius of maximum rotational speed.

Tornado loadings will be combined with other loadings, using the same load combinations required for earthquake but with the earthquake loads replaced with tornado loads. The stress and deformation limits required for earthquake load combinations will be used for the tornado load combinations. All non-Category I items will be designed to withstand the wind loadings for the site as required by ANSI A58.1. The design for tornado and wind loadings will follow in general the recommendations included in "Design Guidelines for Wind-Resistant Structures,"³ which will be furnished by UCC-ND at the beginning of conceptual design.

Tornado-generated missiles and their velocities will be postulated for those facilities which must be designed against missile penetration.

1.6.7 Flooding Design Requirements

All structures, systems, and equipment important to safety will be designed to withstand the effects of floods without loss of capability to perform their safety functions. All flood design requirements will meet the provisions of Regulatory Guide 1.59.

1.6.8 Criticality Criteria

The plant design will conform to all nuclear criticality and safety requirements specified in Regulatory Guide No. 3.4 and ERDA Appendix 0550, Part VI B, Nuclear Criticality Safety.

3. J. R. McDonald, K. C. Mehta, and J. E. Minor, "Design Guidelines for Wind Resistant Structures," prepared for UCC-ND Engineering Division by the Institute for Disaster Research and the Department of Civil Engineering, Texas Technological University, June 1975.

In all areas where wastes are either handled or stored, provisions will be made to ensure that a critical mass cannot be assembled or accumulated, either by accident or design.

1.6.9 Safeguards

Consideration will be given during design to provisions aimed at assuring that nuclear materials are not removed from authorized locations or handled by unauthorized personnel. In addition to the use of strict operating procedures, the facilities will be designed in accordance with Title 10, Part 50, Appendix Q, of the Code of Federal Regulations. Design consideration will be given to providing the capability for unobstructed observation within material access areas. These design considerations will include site security fencing, systems for detection of entry in accordance with Regulatory Guide 5.44, personnel and vehicle access control and monitoring, control of shipping and receiving areas, control point lighting and communications, waste identification, and inventory control.

1.7 Environmental Impact

No significant impact on the environment resulting from either the construction or operation of the facility will be allowed. Minor environmental effects anticipated on the surface of or below the proposed central controlled areas (see Fig. 1 in the Appendix) as well as those beyond the site boundaries will be analyzed and reported in a draft Environmental Impact Statement (EIS) to be prepared by September 1978. The EIS is a separate parallel task and is not assigned as part of this conceptual design effort, though an abbreviated environment impact section will be included in the CDR.

1.8 Quality Assurance

As part of this conceptual design, a quality assurance program will be established in accordance with the requirements of ANSI N45.2, or other standards that may be dictated by NRC licensing criteria, to assure that the quality required for safe, reliable, and economical operation will be achieved. Each major function and/or component of the facility will be classified according to the consequences of its failure, associated safety hazards, and required operational capability and reliability; the commensurate level of effort to obtain the required quality will be determined. The quality assurance program will include provisions for qualitative reliability and maintenance analyses to aid in the formulation of maintenance philosophies and to assure achievement of the design goal of reliable operation of critical systems and components in the plant.

2. FACILITY DESIGN REQUIREMENTS AND CRITERIA

2.1 General Codes, Standards, Specifications, and Regulations

The latest edition of the following codes, standards, specifications, and regulations will apply to the conceptual design of the waste storage plant. Any conflict between these referenced documents and the requirements of the facility design criteria will be brought to the attention of ERDA.

2.1.1 Energy Research and Development Administration Documents

ERDA Manual:

- a. Chapter OR-0524, "Standards for Radiation Protection," March 1969.
- b. Chapter 0550, "Occupational Safety Standards," March 1973.
- c. Chapter 2401, "Physical Protection of Classified Matter and Information," November 1973.
- d. Chapter 2405, "Physical Protection of Unclassified Special Nuclear Material," June 1973.
- e. Appendix 6301, "General Design Criteria," November 1972.

2.1.2 Nuclear Regulatory Commission Documents

Code of Federal Regulations, U.S. AEC Rules and Regulations:

- a. 10-CFR-20, "Standards for Protection Against Radiation," with appendixes.
- b. 10-CFR-30, "Possession and Use of By-Product Materials."
- c. 10-CFR-40, "Possession and Use of Source Materials."
- d. 10-CFR-50, "Licensing of Production and Utilization Facilities," with appendixes.
- e. 10-CFR-70, "Possession and Use of Special Nuclear Materials."
- f. 10-CFR-100, "Reactor Site Criteria."

U.S. AEC Regulatory Guides

- a. Guide No. 1.23 (Safety Guide 23), "Onsite Meteorological Programs," February 1972.
- b. Guide No. 1.29, "Seismic Design Classification," August 1973.
- c. Guide No. 3.12, "General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," January 1974.
- d. Guide No. 3.16, "General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants," January 1974.
- e. Guide No. 3.18, "Confinement Barriers and Systems for Fuel Reprocessing Plants," February 1974.
- f. Guide No. 3.20, "Process Offgas Systems for Fuel Reprocessing Plants," February 1974.
- g. Guide No. 3.22, "Periodic Testing of Fuel Reprocessing Plant Protection System Actuation Functions," February 1974.
- h. Guide No. 3.24, "Guidance on the License Application, Siting, Design, and Plant Protection for an Independent Spent Fuel Storage Installation," December 1974.

i. Guide No. 3.4, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," January 1973.

j. Guide No. 3.7, "Monitoring of Combustible Gases and Vapors in Plutonium Processing and Fuel Fabrication Plants," April 1973.

k. Guide No. 5.44, "Perimeter Intrusion Alarm Systems." January 1975.

2.1.3 Union Carbide Corporation, Nuclear Division Documents

CV-6.1, Technical Specification, "Security Fence." January 1965.

Y-EF-538, "General Design Criteria for UCC-ND Engineering Projects – General Codes, Standards, Procedures, Specifications, and Technical Definitions," Issue No. 3, January 1975.

Y-ES-7.8-1, Standard Reference Information, "Security Fence," January 1965.

2.1.4 American National Standards Institute Documents

ANSI A58.1-1972, "Minimum Design Loads in Buildings and Other Structures. Building Code Requirements for."

ANSI N-13.1-1969, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities."

ANSI N-16.2-1969, "Criticality Accident Alarm Systems."

ANSI N-42.7-1972, "Protection Systems for Nuclear Power Generating Stations."

ANSI N-45.2-1971, "Nuclear Power Plants, Quality Assurance Program, Requirements for."

ANSI N-101.3-1973, "Guide to Principal Design Criteria for Nuclear Fuel Reprocessing Facilities."

ANSI Z-88.2-1969, "Practices for Respiratory Protection."

2.1.5 Other

a. American Railway Engineering Association (AREA) Standards.

b. Tunnel Safety Orders, Administrative Code, State of California.

c. Mine Safety Orders, Administrative Code, State of California.

2.2 Site Criteria

No specific sites have yet been considered for the waste storage plant. Site selection studies are in progress, but specific site selection and acquisition will not be made in time for use in the conceptual design. Therefore, generic site criteria will form the basis from which to proceed with conceptual design.

2.2.1 General Site Description

The specific site to be selected will feature a controlled area, consisting of an inner control area which extends over approximately 3 square miles, surrounded by a circular outer control area. The inner control area is to be acquired in fee simple. Complete subsurface rights are required for both control areas so that all mining and drilling operations can be regulated. Restrictions on the use of the outer control area may be relaxed at some future time should data become available to justify such action. These are shown schematically in Fig. 1 in the Appendix.

The site is assumed to be gently rolling terrain presently devoted primarily to agricultural uses. Furthermore, the site is assumed to have only intermittently flowing surface streams. Circulating groundwater is described in Sect. 2.2.2, Geology. The site has an assumed proximity to a major railroad line and to a major highway.

2.2.2 Geology

The stratigraphy that will probably be encountered will consist generally of two types of dome salt deposits and one typical bedded salt deposit. For the dome deposits, unconsolidated sands, silts, and clays are present from the surface to a depth of about 85 ft in Case A (Fig. 4) and to 658 ft for Case B (Fig. 5). In both cases, anhydritic cap rock lies between the unconsolidated deposits and the underlying rock salt. Some faulting and/or slumping of the rocks above and in close proximity to the salt also occurs. The Case A dome is nearly cylindrical in shape with a diameter of about $\frac{3}{4}$ mile, while the Case B dome is elliptically shaped with dimensions of about 1 and 3 miles.

For the bedded deposits, rather impermeable shale would be encountered from the surface to a depth of about 100 ft (Fig. 6). Below the shale, interbedded limestone and dolomite would persist to about 450 ft. From 450 to 550 ft below the surface, rock salt would be encountered, then more than 1000 ft of massive dolomite. Underlying this are the thick beds of rock salt that would be the potential host rocks for wastes. All of the strata is nearly flat-lying, with dips on the order of 30 to 40 ft/mile. Some small quantities of circulating groundwater would be expected in most of the rocks above the salt; however, rather prolific water-bearing carbonate rocks may occur in the zone between about 1200 and 1400 ft.

The site will be situated in a zone of tectonic stability.

The architect-engineer will devote his efforts to only one of two formation types as directed by ERDA and recommended by UCC-ND.

2.3 Land Improvement Criteria

Improvements to land will consist of the grading and landscaping necessary to accommodate all structures and facilities and to control storm-water runoff. These improvements will include the provision of roadways, parking areas, access drives, walks, security facilities and fencing, railroads, and utilities.

2.3.1 Site Clearing, Grading, Drainage, and Landscaping

Site clearing will be held to a minimum, and areas not affected by construction activity are to be left in their natural state. For those areas where construction will take place, all trees, stumps, brush, and topsoil will be removed. Topsoil will be stockpiled for use in subsequent landscaping.

Grading plans will minimize the area disturbed by construction activities and will provide for the restoration of all disturbed areas. The only grading done will be that necessary to accommodate structures and facilities and to provide transportation, parking areas, utilities, drainage ditches, and adequate surface drainage control. Storm sewers with free outlets to existing water courses will be provided to convey rainfall collected by catch basins, roof drains, and subsurface drainage systems. For estimating rainfall, the ten-year rainfall curve, published by the U.S. Weather Bureau, and a time period of 60 min will be used, except for critical facilities. For these, the provisions of Regulatory Guide 1.59 will be used (Subsect. 1.6.7).

Landscaping will be limited to the restoration of ground cover in the areas disturbed during construction operations. Local grasses will be replaced to provide adequate protection against erosion. Adequate topsoil, fertilizer, and mulch will be applied to assure complete coverage of the disturbed areas.

2.3.2 Fencing

Exclusion security fencing will be provided around the perimeter of the inner controlled area. Fencing design will be in accordance with the requirements of ERDA Manual Appendix 2401, Part II, C.3.a. Similar perimeter fences will be provided around all shafts; buildings which receive, handle, and store wastes; explosive magazines; substations; and other facilities which may later be determined to require security

fencing. Swing-type vehicular gates will be provided where roadways and railways enter the site and at certain fences inside the inner controlled area. All fencing will be grounded in accordance with ERDA Manual Appendix OR-6301, and fence installations which cross power corridors will be further grounded in accordance with that same document. Barriers will be provided at points where the perimeter fence crosses the surface drainage system ditches.

2.3.3 Transportation

Access to the site will be by new roadways and railways from the nearest available highways and railroads with adequate capacity to handle the projected traffic. The access roads will be provided by the local government.

2.3.3.1 Roads and parking areas. A roadway network within the site consisting of primary and secondary roads will be provided. All roads will be classed as primary except those which service the ventilation shafts and substations.

Primary roads will have two 12-ft-wide lanes with 6-ft-wide shoulders. Secondary roads will be a single 12-ft-wide lane with 4-ft-wide shoulders. All roadway sections are assumed to consist of 1 1/2 in. of asphaltic concrete over 8 in. of compacted aggregate subbase. This pavement section will be founded on not less than 6 in. of compacted subgrade made from suitable material. The shoulders will consist of 6 in. of compacted aggregate base course material on compacted subgrade with a single bituminous surface treatment. Transverse drainage slopes of 2% for the traveled way and 5% for the shoulders will be used. Parking areas large enough for the initial personnel complement and arranged for future expansion will be provided. Parking will be provided outside the exclusion fence for employee and visitor private vehicles and inside the exclusion fence for plant vehicles. All parking lots and aprons will be of the same structural section as the roadways.

2.3.3.2 Railroads. A standard-gage railroad extension to the site will be required, with sidings on the site to accommodate loaded and unloaded railcars which have an overall length of 66 ft each. The track layout will provide for future extension for both loaded and empty cars. A means for moving railcars on the site will be provided without depending on commercial rail switching service. The railroad installation will conform to ERDA General Design Criteria Appendix 6301 and the AREA standards.

2.3.4 Sealing Abandoned Wells

All penetrations into or through the salt deposit within the controlled areas will be sealed prior to commencing any waste burial activities, to preclude entrance of water into the salt. A separate parallel study which is not part of this conceptual design will provide criteria for later design efforts in borehole plugging.

2.3.5 Mined Salt Storage

On-site storage of mined salt will be provided.

2.4 Low-Level Waste Facility Criteria

The LLW facility will provide for unloading truck and rail shipments of low-level wastes, inspection and monitoring of shipping containers and waste drums, overpacking damaged waste drums, transporting waste drums to the mine level, and mine-level retrievable storage of the waste containers. The LLW surface facilities and mine-level transfer facilities will be designed to handle low-level waste quantities projected

through the year 2005 (see Sect. 1.5.3). The low-level mine facilities will be initially sized for a capacity of 53,000 drums. Initial operation will be on a single-shift, five-day-work-week schedule, but the facility will be designed to eventually allow operation on a schedule of three shifts per day, five days per week. The low-level waste handling facilities will not be designed to handle low-level wastes containing sources of penetrating (gamma) radiation exceeding 0.25 millirem/hr at the surface.

The principal components of the low-level waste facility are:

1. low-level waste receiving building,
2. low-level waste transfer shaft, hoist, and cage,
3. low-level mine,
4. upcast ventilation shaft and central filter station,
5. low-level waste facility ventilation and confinement system.

The low-level waste receiving building will have entry airlocks of sufficient size to accommodate (1) an 8 X 20 X 8 ft high cargo container; (2) confined unloading and decontamination rooms with adequate floor area to permit survey and decontamination of a cargo container, unloading and interim storage of the entire contents of a cargo container, as well as overpacking and decontamination of any damaged waste containers; (3) a transfer room in which lift trucks can be utilized to move waste drums from the unloading room to the assay room and to the mine shaft; (4) the mine shaft entry and hoist room; (5) the supporting change room, counting room, shift operations office, health physics office, maintenance area, battery charge room, mechanical and electrical equipment rooms, and exhaust fan filter room.

The low-level waste shaft, hoist, and cage will provide access from the receiving building to the mine level. The low-level mine will provide space for retrievable storage of the low-level waste drums. The upcast ventilation shaft and central filter station will provide atmospheric exhaust for mine ventilation air. The low-level waste facility ventilation and confinement system will provide for radioactive containment and mine ventilation.

Areas that are to be designed for radioactive confinement are the entry air airlocks, unloading and decontamination rooms, nondestructive assay room, transfer room, exhaust fan filter room, low-level waste mine shaft, shaft head frame, hoist cable enclosure, and hoist house.

2.4.1 Low-Level Waste Receiving Building

The following general criteria will be used as a guide in the design of the LLW receiving building:

1. The building will be constructed so as to prevent the spread of radioactive contamination from the operational areas to the nonoperational areas. Airlocks will be provided at all entrances and exits opening into potentially contaminated areas. Ventilation air flow will be from the clean areas into areas of potentially increasing radioactive contamination.
2. The normal operational functions of the waste receiving building will not have to be interrupted while a cargo container containing a failed burial unit is being decontaminated.
3. The waste transfer shaft will be isolated from the waste receiving building and from the mine by ventilation control doors.
4. Contaminated liquid waste generated in the operation of the building will be collected and transported to the Canistered Waste Facility for concentration and disposal.
5. Water from the floor drains in the radioactive confinement areas will be collected in an underground tank sized to accommodate a 20-min discharge of all the fire sprinklers in the largest radioactive confinement area room.

6. Contaminated solid waste generated in the operation of the building will be packaged in drums, sealed, and buried in the low-level mine.

A weather-protected area will adjoin the waste receiving building for the unloading of ATMX railcars and trucks. Sufficient space will be provided for the removal of 8 X 20 X 8 ft cargo containers from the railcar or truck by an overhead bridge crane and for the positioning of the cargo containers on transfer cars. Additional space is required in the unloading area for the interim storage of railcar hatch covers and decontaminated empty cargo containers. The unloading area will also be used to load empty cargo containers into ATMX cars or onto trucks for return to the shipper.

A room will be required in the confinement area for a nondestructive assay of the waste drums. This room will be shielded with normal concrete and will have a door to permit a lift truck to transfer in and remove the waste drums.

The change room will be located adjacent to the confinement structure in an area of minimum contamination potential and low radiation background. There will be no direct personnel access into the counting room from the confined area, and no shielding is required in the counting room.

Space will be provided in the unrestricted area for an operations office and a health physics office.

A maintenance and battery charge area will be provided in or near the building for routine maintenance of operating equipment.

Normal electrical service, consisting of 120, 240, and 480 V, will be provided for the LLW receiving building. Welding receptacles will be provided in the railcar unloading area, in the transfer room, in the maintenance area, and in the mechanical equipment room. A 120-V electrical service strip will be installed around the periphery of the counting room. Since the counting work will be low level, incandescent lights will be used in the counting room to minimize background effects.

Electrical service will be required for the battery charging station in the maintenance room. Electrical requirements for the assay room will be determined by equipment demands.

Design conditions for heating, ventilation, and air conditioning will be based on data published in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) *Handbook of Fundamentals*. Outside design temperatures for summer are 99°F dry bulb and 76°F wet bulb. The outside design temperature for winter is -5°F. Inside design conditions will be 76°F dry bulb without humidity control for all air-conditioned spaces, and for spaces not air-conditioned 65°F in winter, without humidity control, and 105°F maximum in summer.

2.4.2 Low-Level Waste Shaft, Hoist, and Cage

The shaft, hoist, and cage provide access to the waste and allow its transfer from the receiving building to the mine level. The shaft will be located in accordance with the developed master plan of the mine.

The shaft will be sized to accept a cage in which waste drums can be transferred to the mine. It will be constructed in a manner to prevent inward seepage of groundwater, will be free of cracks and pits, and will be amenable to decontamination by brushing or other abrasive techniques.

The hoist will be designed to routinely lower waste drums to the mine level. It will be semiremotely operated and will be equipped with a magnetic braking system.

The waste transfer cage will be designed to provide confinement during the transfer of waste drums from the waste receiving building to the mine level. Engineered openings will be provided at the waste receiving building and at the mine level between the shaft and the cage to ensure a minimum probability of activity transfer in the event of a loading or unloading accident. The cage will be equipped with safety mechanisms which will actuate under emergency conditions.

2.4.3 Low-Level Mine

The low-level mine will be sized initially to handle 53,000 fifty-five-gallon drums of low-level waste. This waste has a thermal rating that is inconsequential in terms of storage effects; therefore salt extraction of up to 50% is possible. Since no shielding is required, the storage configuration is simplified to a warehousing problem and is dealt with in terms of square footage.

All mining that is anticipated for the plant phase is to be accomplished prior to plant operation, and salt disposal will consist of surface storage.

The overall mine arrangement will include areas for support functions such as underground maintenance, first aid, material storage, mine level shift office, and underground equipment.

The mine will be ventilated with air supplied from the surface and directed through the mine by the use of brattices. The low-level mine ventilation exhaust air will be combined with the ventilation exhaust from the canistered mine and will be filtered through two banks of HEPA filters in series, preceded by prefilters, and monitored before discharge to the atmosphere. Consideration should be given to electric-powered equipment to minimize the volume of ventilation air required for the mine.

The mine will be designed in accordance with the mine master plan.

2.4.4 Upcast Ventilation Shaft and Central Filter Station

The upcast ventilation shaft will be located in accordance with the mine master plan. The shaft will be sized to accommodate the design exhaust air flow for the combined ultimate burial capacity of both the canistered waste and the low-level mines. It will be designed to provide a surface suitable for decontamination, and precautions will be taken to ensure that the shaft is free of cracks and crevices through which groundwater could seep into the shaft.

The central filter station will be adjacent to the top of the upcast ventilation shaft. It will be designed for radiological confinement and will be watertight. The station will contain all the fans, dampers, and filtration equipment required for controlling and cleaning the mine exhaust air before it is released to the atmosphere. Removable roof plugs will be provided to permit access for major equipment maintenance and filter changeout. Provisions will be made for "bagging out" the filters.

The filter station will contain banks of filters composed of a 90% NBS filter bank and two banks of HEPA filters, all in series. Three sets of filter banks will be provided so that when one bank is removed from service, the two remaining banks will handle 80% of the normal flow. The HEPA filter banks will be separately testable by the diocphalate (DOP) method.

The exhaust stream will exit from the filters through blast dampers (for protection of the filter banks from tornado pressures) and will discharge to the atmosphere through a stack. The stack will be located at least 500 ft from the security fence plant boundary.

2.4.5 Low-Level Waste Facility Ventilation and Confinement System

The LLW receiving building will be operated at a negative pressure with respect to the atmosphere. Ventilation flows will be controlled by pressure differential from areas of low contamination potential. Pressure differential will be maintained by the resistance of individual items or a combination of items consisting of dampers, backflow preventers, filters, grilles, louvers, and fans.

The radioactive compartment and the nonradioactive zones of the waste receiving building will be ventilated by independent exhaust and control systems. The nonradioactive zones will be air-conditioned and vented with a minimum of six air changes per hour. Fresh makeup air will be filtered through a prefilter (30% NBS) and main filter (90% NBS) before distribution. The exhaust air will be passed through, in series, a 30% NBS filter, a 90% NBS filter, and an HEPA filter before discharge to the atmosphere. Since

the air that is being processed has a low contamination potential, the exhaust system need not have auxiliary backup capabilities and need not be tied into the standby power network.

2.5 Canistered Waste Facility Criteria

The canistered waste facility will include the facilities and equipment required to receive and handle canisters of waste which require shielding. These wastes include high-level wastes, cladding hulls, and intermediate-level wastes, which are all shipped to the plant in shielded shipping casks. At the plant the canistered waste is removed from the shipping cask, and if the cask is damaged, the waste is overpacked before being transported to the appropriate canistered waste mine area. The initial mine capacity for canistered waste will be 1000 canisters of HLW, 3100 canisters of cladding hulls, and 26,000 canisters of ILW. However, surface and transfer facilities for the canistered waste will be based on accommodating the wastes projected through the year 2005 (see Sect. 1.5.3). The plant will initially operate on a single-shift-per-day, five-day-work-week schedule. The repository will later be expanded to a three-shift-per-day operation.

The canistered waste facility will include the following:

1. canistered waste receiving building,
2. canistered waste transfer shaft, hoist, and cage,
3. canistered waste storage mine,
4. canistered waste facility ventilation and confinement system,
5. canistered waste facility process waste system.

2.5.1 Canistered Waste Receiving Building

The canistered waste receiving building will provide facilities and space to receive and unload from railroad cars shipping casks weighing up to 110 tons; to cool the surface of the waste cans and the internal cavity of the shielded casks; to transfer the waste cans from the shipping cask to the hoist; to provide minimum support functions specifically related to the canistered waste receiving building; and to process all radioactive liquid wastes generated at the plant.

The canistered waste receiving building will have an airlock of sufficient size to accommodate a 66-ft-long railcar carrying shipping casks; a cask unloading area, sized to permit unloading of the shipping cask from the railcar and cooling of the cask internals; a cask cleaning area; a shielded transfer cell for remote unloading of individual waste cans from the shipping cask and transfer of them to the canistered waste mine shaft; a cell operating gallery with space to perform remote in-cell operations and permit removal of manipulators for maintenance; the basic structure of a shielded overpack cell for future equipping and operation; space for process equipment associated with cask cooling and liquid waste collection, concentration, and solidification; a canistered waste mine shaft hoist house and head frame; and supporting change room, chemical laboratory, counting room, health physics office, maintenance and storage area, mechanical equipment room, and operations office.

Areas containing operations in which the integrity of the shielded cask is breached, such as for attaching cooling or decontamination lines to the interior of the cask and for transferring cans from the cask, will be confined. Other areas which will be designed for radioactive confinement are the cell operating gallery, the hoist house and head frame, the railcar airlock, the process equipment areas, and the mechanical equipment rooms.

Space will be provided (1) for material storage and equipment maintenance as required for efficient functioning of the building; (2) for housing building mechanical equipment; (3) for a chemical laboratory, located for convenient access to the counting room and providing facilities for routine activity analyses of cask coolant samples, liquid waste effluents, repurified water, and for routine chemical analyses on brine samples and decontamination and coolant solutions as required; (4) for an office to serve as an operations supervisor's office; and (5) for a health physics station located for easy access to the cask unloading area.

The counting room will be located adjacent to the confinement structure in an area of minimum contamination potential and low radiation background. There will be no direct personnel access into the counting room from the confined area, but a pass-through window will be provided for transfer of counting samples. No shielding is required in the counting room.

The change room facilities will be located in the nonrestricted area and will serve as a buffer zone or airlock for the normal flow of personnel traffic between the confinement and nonrestricted areas.

Normal electrical service, consisting of 120, 240, and 480 V, will be provided for the canistered waste receiving building. Welding receptacles will be provided in all remote operating galleries, all cask unloading and handling areas, process equipment areas, the mechanical equipment rooms, and the maintenance shop.

Electrical service of 120 V will be provided around the periphery of the counting room. Since most of the counting work will be low level, incandescent lighting will be provided in the counting room to minimize background effects.

Design conditions for heating, ventilation, and air conditioning will be based on data published in the *ASHRAE Handbook of Fundamentals*. Outside design temperatures for summer are 99°F dry bulb and 76°F wet bulb. The outside design temperature for winter is -5°F. Inside design conditions will be 76°F dry bulb with no humidity control for all air-conditioned spaces, and for spaces not air-conditioned 65°F in winter, without humidity control, and 105°F maximum in summer.

The shielded transfer cell will require cooling to dissipate the design heat load of a shielded cask filled with waste cans. The cell cooling system will be supplied with standby power to preclude overheating of the cell equipment from waste canister decay heat during prolonged outages of normal power.

2.5.2 Canistered Waste Shaft, Hoist, and Cage

A shaft will be provided through which waste canisters can be transferred to the mine from the surface facilities in the canister receiving building. The shaft diameter will be selected to accommodate the previously described reference canister contained in an appropriate overpack and a protective cage. The interior surface of the shaft will be free of cracks and pits and will be amenable to decontamination by brushing or other techniques. The design must include provisions to prevent groundwater from entering the mine. The location of the shaft will be in accordance with the mine master plan.

The shaft hoist may be either a mine type or an elevator hoist, providing the latter is acceptable under applicable mining laws. The hoist will have a magnetic braking system, and dual cables will be provided on the hoist.

2.5.3 Canistered Waste Mine

The canistered waste mine will be sized initially to accommodate quantities of HLW, cladding hulls, and ILW available through 1990, with planned expansion according to the mine master plan to handle the wastes projected through the year 2005. The canistered waste will be received at the mine level in a shielded receiving station with viewing gallery and transported in a specially designed transporter to the specific area of the mine dedicated to that type of waste. (The transporter design is not part of this conceptual design, and specific information on the transporter will be supplied as available.) The waste canisters will be placed

in predrilled, sleeved, vertical holes along the centerline in each mine storage bay floor. Shield plugs will be provided which are flush with the floor. Each canistered waste type will have separate storage hole arrays and each hole will be suitably identified and labeled with waste pedigree information. A typical envisioned emplacement for an HLW canister is shown in Fig. 3 in the Appendix. Storage arrays are to be designed conservatively, based on a maximum heat load of 158 kW/acre and 5000 W/canister for HLW and 55 W/canister for cladding hulls. At 0.13 W/canister for ILW, thermal loads do not govern; but it is considered preferable to use a storage arrangement similar to that for cladding hulls, since the ILW requires shielded handling and storage.

All mining anticipated for the initial phase is to be accomplished prior to plant operation, and salt disposal will consist of surface storage.

2.5.4 Canistered Waste Ventilation and Confinement System

2.5.4.1 Canistered waste surface facilities. The canistered waste receiving building will be operated at a negative pressure with respect to the atmosphere. Ventilation flows will be controlled by pressure differential from areas of low contamination potential to areas of successively higher contamination potential. Pressure differentials will be maintained by the resistance of individual items or a combination of items consisting of dampers, backflow preventers, filters, grilles, louvers, and fans.

The shielded transfer cell will require cooling to dissipate the design heat load of a shielded cask filled with waste cans. The cell cooling system will be supplied with standby power to preclude overheating of the cell equipment from waste can decay heat during prolonged outages of normal power.

Normally inhabited areas of confinement zones will be ventilated with six to ten air changes per hour, except for the cask unloading area, which will have a minimum of three changes per hour. Fresh makeup air to all confinement zones will flow through prefilters (30% NBS), main filters (90% NBS), HEPA filters, and a backflow preventer before being distributed to these areas. Exhaust air from all confinement zones will be processed through a 30% NBS filter, a 90% NBS filter, two banks of HEPA filters in series (separately DOP testable), and then discharged to the atmosphere. A duplicate filter bank and exhaust fan installation will be provided to ensure reliability of operation, except for the high-level hoist house. Both fans will be tied into the standby power distribution system. Upon loss of normal power, the confinement zone ventilation supply system will automatically shut down, and the exhaust fan will automatically operate at half-speed.

The nonrestricted areas of the building, except the maintenance area, will be supplied with fresh air filtered through 30% NBS and 90% NBS filters. The exhaust from nonrestricted areas, except the maintenance area and the operations office, will be filtered through 30% NBS and 90% NBS filters and a single bank of HEPA filters before discharge to the atmosphere. The maintenance area and operations office will be given conventional ventilation treatment. Ten air changes per hour will be supplied to the change room, chemical laboratory, and health physics office. Design conditions for heating, ventilation, and air conditioning will be based on data published in the *ASHRAE Handbook of Fundamentals*. Inside design conditions will be 76°F dry bulb with no humidity control for all air-conditioned spaces, and for spaces not air-conditioned 65°F in winter, without humidity control, and 105°F maximum in summer.

2.5.4.2 Canistered waste mine ventilation. Mine ventilation air will be supplied to all underground facilities from the surface. The air to the high-level mine will be directed through the areas where mining operations are being carried out, filtered, then routed through the areas where wastes are being buried, filtered locally again, and finally exhausted through the upcast ventilation shaft and filtered at the surface, after being combined at mine level with the exhaust from the low-level mine.

2.5.5 Canistered Waste Facility Process Waste System

All radioactive process waste generated in both the low-level and canistered waste facilities will be processed locally by process waste fixation equipment located within the canistered waste facility. A liquid waste collection and processing system will be provided, which will concentrate the liquid waste by evaporation and solidify the concentrate in a form suitable for burial in the mine. The evaporator distillate will be decontaminated by ion exchange for reuse at the plant or for evaporation to the atmosphere. Aqueous concentrations will be solidified by mixture with cement and allowed to harden in drums, whereupon they will be stored in the mine.

2.6 Support Facilities Criteria

Support facilities will consist of an administration building, maintenance shops, warehouse, fire house, and security building. These facilities will be initially designed to accommodate the plant population projected through 1990 and to permit future expansion as may be projected beyond 1990.

2.6.1 Administration Building

The administration building will be located near the low-level waste building. It will provide centralized office space, lunchroom facilities, a conference room for administrative personnel, and space for functions such as plant management, engineering, accounting, personnel, safety, payroll, central files and records, and medical (see ERDA Manual Appendix 6301, Part II, A).

2.6.2 Maintenance Shops

General maintenance facilities will be provided for repair and maintenance of noncontaminated plant equipment, automotive equipment, and facilities. Separate maintenance facilities for mining, waste burial, and underground support equipment that is impractical to raise to the surface will be provided underground (see ERDA Manual Appendix 6301, Part II, D).

2.6.3 Warehouse

A centralized storage facility will be provided to house the supplies and spare parts inventory for the plant. The warehouse facility will include fuel storage appropriately designed for projected fuel demands and for applicable fire, safety, and spill control criteria (see ERDA Manual Appendix 6301, Part II, C).

2.6.4 Security Building

A security building will be provided at the main plant entry gate. This building will house plant protection and security facilities, including security police headquarters, a visitor control center, a vehicular access gatehouse, a central monitoring and alarm station, fire protection equipment, and an ambulance. The central alarm station will include the master instrument and control panel and will have provisions for transmitting alarms to the vehicular access gatehouse.

2.7 Utilities and Services Criteria

The utility systems required to service the waste storage site include potable and fire protection water, electrical power (normal and standby), sanitary waste disposal, fuel gas, communications, and site and regional monitoring systems.

2.7.1 Water

The water requirements for the site will be provided by a combined supply and distribution system for both domestic and fire protection water. The water source will be the nearest available utility system having adequate capacity. A looped piping system will be provided around the main facilities inside the inner controlled area, with fire hydrants and laterals supplying the separate individual facilities. An elevated storage tank providing distribution pressure and reserve capacity for fire protection demand will be provided. Standby booster pumps to satisfy high demand for fire protection water will also be included.

The potable water system will provide an adequate supply of water to all sanitary, utility, and process use points. Sanitary requirements will be established on a fixture unit basis in accordance with the National Plumbing Code. Supply connections will be provided as required to all process equipment. All process connections will be made through an air gap or an approved reduced-pressure-principle backflow preventer to preclude contamination of the potable water system.

Fire protection will be provided by a wet pipe sprinkler system supplemented by portable fire extinguishers. Sprinkler heads in confinement areas will be on-off type and in other areas will be rated at 165°F. Water drainage from the discharge of sprinklers in confinement areas will be routed to intercepting trenches and to a waste collection tank for subsequent monitoring, processing, and disposal.

2.7.2 Electrical Power

Normal power supply will be received at the facility from a utility-owned substation at the site. Distribution voltages to use points at surface and mine levels will depend on individual use requirements.

All standby electric power will be provided by diesel-generator units.

A 120-V battery station will be provided to supply emergency lighting and power for all instrumentation and control systems requiring noninterruptible power.

2.7.3 Sanitary Waste

A sanitary waste system will be provided to collect and dispose of all the sanitary waste generated in the above-ground portion of the plant facilities. Treatment of the sanitary wastes will be done on-site with a packaged, factory-assembled sewage treatment plant, providing the equivalent of primary and secondary treatment meeting the applicable state and federal requirements. Sanitary wastes that are generated in the mine will be collected in self-contained chemical toilets which will either be serviced by a contractor for disposal off-site or will be handled in the on-site treatment plant. Wastes from potentially contaminated sources will not be discharged to the sanitary waste system.

2.7.4 Fuel

Coal will be the primary fuel base for the plant, with natural gas and No. 2 fuel oil as auxiliary fuels.

2.7.5 Steam

Heating and process steam will be generated using fire tube boilers firing coal as the primary fuel. Main steam supply conditions will be 250 psig, saturated. Packaged water treating facilities will be provided to process boiler feedwater. Condensate return will be explored and utilized if deemed appropriate.

2.7.6 Communications

The plant communication system will be a combined telephone-intercom system consisting of service provided by a local commercial telephone exchange. For emergency backup, a two-way shortwave radio

communication system will be provided to allow communication between strategic points in the plant and with outside emergency organizations.

The fire alarm system will be activated by either fire alarm pull boxes, heat-activated detectors in confined areas, or sprinkler flow detectors. The fire alarm signals will be transmitted over a paging system.

2.7.7 Site and Regional Monitoring and Surveillance

Site monitoring equipment will include stack samplers, alpha and beta-gamma detectors, and gas flow measuring equipment in the plant exhaust air stack. There will be perimeter air and fallout monitors near the site boundaries, and surface storm-water drainage monitors at appropriate locations where the drainage leaves the site.

Radiation monitoring of the region outside the plant perimeter will include measurements of surface contamination and radiation dosage, and periodic tests of groundwater, surface water, and vegetation to provide a continuing evaluation of the effect of plant operation on the environment.

APPENDIX

1. Terminology

1. **bedded salt** — a stratified salt deposit
2. **canistered waste** — those wastes which require shielding and are placed in retrievable storage canisters: high-level waste, cladding waste, and intermediate-level wastes.
3. **CDR** — Conceptual Design Report
4. **central area** — a fenced area within the inner controlled area which contains all surface facilities
5. **cladding wastes** — solid fragments of zircaloy and stainless steel cladding and other structural components of the fuel assemblies that remain after the fuel cores have been dissolved. These fragments are compacted to 70% of theoretical density. In addition to neutron-induced radioactivity, the cladding waste contains 0.05% of the actinides and 0.05% of the nonvolatile fission products in the spent fuel.
6. **DOT** — Department of Transportation
7. **drummed waste** — low-level waste which does not require shielding and is packaged in nominal 55-gal drums for retrievable storage
8. **EIS** — Environmental Impact Statement
9. **ERDA** — Energy Research and Development Administration
10. **federal repository** — initial plant facility with expanded mine-level storage capability, approximately 2000 acres when totally developed. The retrievability feature may be eliminated.
11. **high-level waste** — solidified composites of all the liquid waste streams arising from the reprocessing of spent fuels. These wastes contain more than 99.9% of the nonvolatile fission products, 0.5% of the uranium and plutonium, and all the other actinides formed by transmutation of the uranium and plutonium in the reactor.
12. **inner controlled area** — fee simple acquired 1-mile radius, approximately 2000 acres. In this area there is drilling or mining and only selected surface activity. The area encloses the maximum extent of the underground development.
13. **intermediate-level waste** — those solid or solidified materials (other than high-level and cladding wastes) that contain long-lived alpha emitters at concentrations greater than 10 nCi/g, and have typical surface dose rates between 10 and 100 millirems/hr after packaging as a result of fission product contamination. Sometimes called "high gamma transuranic wastes" or "alpha-beta-gamma wastes."
14. **low-level transuranic wastes** — those solid or solidified materials that contain plutonium or other long-lived alpha emitters in known or suspected concentrations greater than 10 nCi/g, and yet have sufficiently low external radiation levels after packaging that they can be handled directly. Sometimes called "alpha waste" or "low-gamma transuranic wastes."

15. **LWR** – light-water reactor
16. **NRC** – Nuclear Regulatory Commission
17. **NWTSP** – National Waste Terminal Storage Program
18. **outer controlled area** – 2-mile annulus, approximately 16,000 acres, surrounding the plant facility. This area features perpetual acquisition of subterranean rights; all existing holes are plugged; drilling and mining are only selectively allowed; and there is no restriction on surface usage.
19. **overpacks** – secondary or additional external containment for packaged radioactive wastes
20. **OWI** – Office of Waste Isolation, a division of UCC–ND
21. **retrievability** – capability to remove waste from storage
22. **Q.A.** – quality assurance
23. **salt dome** – structurally deformed salt formation characterized by local uplift, approximately circular in outline
24. **TAD** – Technical Alternatives Document: ERDA-76-43, "Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle"
25. **UCC–ND** – Union Carbide Corporation–Nuclear Division

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ORNL DWG 76-17206

- A** CENTRAL AREA...
100 ACRES WITHIN INNER CONTROLLED AREA, FENCED, CONTAINS ALL SURFACE FACILITIES
- B** INNER CONTROLLED AREA...
FEE SIMPLE ACQUISITION OF ABOUT 2000 ACRES (1-MILE RADIUS), NO DRILLING OR MINING ALLOWED AT ALL, SOME SURFACE RIGHTS MAY BE LEASED SELECTIVELY.
THIS AREA ENCLOSES THE MAXIMUM EXTENT OF UNDERGROUND DEVELOPMENT.
- C** OUTER CONTROLLED AREA...
ACQUISITION OF PERPETUAL SUBTERRANEAN RIGHTS* FOR ABOUT 16,000 ACRES (2-MILE ANNULUS), ALL EXISTING HOLES PLUGGED, DRILLING AND MINING TO BE CONTROLLED AND ONLY SELECTIVELY ALLOWED, SO THAT THE SAFETY OF THE REPOSITORY IS NOT COMPROMISED, NO RESTRICTIONS ON SURFACE USAGE.
- *IN SOME STATES, FEE SIMPLE ACQUISITION MAY BE REQUIRED.

Fig. 1. Control zones for waste repository.

Fig. 2. High-level waste canister.

Fig. 3. Waste canister salt emplacement.

ORNL DWG 76-17208

Fig. 4. Dome salt stratigraphy "A".

ORNL DWG 76-17209

Fig. 5. Dome salt stratigraphy "B".

ORNL DWG 76-17210

Fig. 6. Bedded salt stratigraphy.

ORNL DWG 76-20347

Fig. 7. Block flow diagram - low-level waste.

ORNL DWG 76-20348

Fig. 8. Block flow diagram – canistered waste.

Fig. 9. Projected accumulation of solidified high-level waste at federal repository.

Fig. 10. Projected accumulation of cladding waste at federal repository.

Fig. 11. Projected accumulation of intermediate-level transuranic waste at federal repository.

Fig. 12. Projected acculation of low-level transuranic waste at federal repository.

Table 1. Parameters for conceptual design of a waste storage system in rock salt

Waste type	Criteria table number (Blomeke and Kee table ^a)	Physical form	Heat generated (W/unit)	Units in initial phase ^b	Units in full facility ^c
HLW (ten-year-aged)	2 (2)	Canisters	1800	1,000	35,300
Cladding hulls (five-year-aged)	3 (3)	Canisters	55	3,100	52,200
ILW-TRU	4 (10)	Canisters	1.3×10^{-1}	26,000	265,000
Low-level TRU	5 (9)	55-gal drums	2.2×10^{-1}	53,000	674,000

^aFrom J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated," Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colorado, July 11-16, 1976, CONF 76-0701.

^bCapacity of initial phase allows for retrievable storage of half of all wastes generated through the year 1990.

^cCapacity of repository allows for storage of all wastes generated through the year 2005.

Table 2. Projected annual accumulation of solidified high-level waste available to a federal repository^a

Year	Annual addition					Accumulation through end of year					
	Volume (10 ³ m ³)	Actinide mass (MT)	Radio- activity (MCI)	Thermal power (MW)	Number of shipments	Volume (10 ³ m ³)	Actinide mass (MT)	Radio- activity (MCI)	Thermal power (MW)	Volume needed for dilution (m ³)	
										Air	Water
1988	0.04	2.8	102.64	0.4	20	0.04	2.8	103	0.4	3.2 × 10 ¹³	6.9 × 10 ¹³
1989	0.09	5.5	216.90	0.7	40	0.13	8.3	316	1.1	1.0 × 10 ¹⁴	2.1 × 10 ¹⁴
1990	0.15	9.9	421.46	1.5	72	0.28	18.2	726	2.5	2.3 × 10 ¹⁴	4.9 × 10 ¹⁴
1991	0.18	11.5	542.37	1.9	84	0.46	29.7	1,243	4.3	3.9 × 10 ¹⁴	8.4 × 10 ¹⁴
1992	0.18	11.5	564.87	2.0	84	0.64	41.3	1,766	6.0	5.6 × 10 ¹⁴	1.2 × 10 ¹⁵
1993	0.18	11.5	554.56	1.9	84	0.82	52.8	2,263	7.7	7.2 × 10 ¹⁴	1.5 × 10 ¹⁵
1994	0.22	14.3	662.85	2.3	104	1.04	67.1	2,855	9.7	9.1 × 10 ¹⁴	1.9 × 10 ¹⁵
1995	0.26	17.9	789.35	2.9	124	1.30	85.0	3,556	12.3	1.4 × 10 ¹⁵	2.4 × 10 ¹⁵
1996	0.31	21.8	920.50	3.7	144	1.61	106.9	4,367	15.5	2.2 × 10 ¹⁵	2.9 × 10 ¹⁵
1997	0.38	27.8	1153.58	4.7	180	1.99	134.7	5,388	19.7	3.4 × 10 ¹⁵	3.6 × 10 ¹⁵
1998	0.36	25.2	1093.31	4.2	168	2.35	159.9	6,318	23.2	4.2 × 10 ¹⁵	4.2 × 10 ¹⁵
1999	0.41	28.3	1242.93	4.8	190	2.76	188.2	7,372	27.2	5.1 × 10 ¹⁵	4.9 × 10 ¹⁵
2000	0.45	32.8	1396.70	5.7	212	3.21	221.0	8,550	31.9	6.4 × 10 ¹⁵	5.7 × 10 ¹⁵
2001	0.50	36.3	1557.43	6.3	234	3.71	257.3	9,856	37.2	7.8 × 10 ¹⁵	6.5 × 10 ¹⁵
2002	0.55	41.2	1721.29	7.3	253	4.26	298.6	11,289	43.2	9.7 × 10 ¹⁵	7.4 × 10 ¹⁵
2003	0.61	45.0	1894.34	7.9	284	4.87	343.5	12,855	49.7	1.2 × 10 ¹⁶	8.4 × 10 ¹⁵
2004	0.66	48.7	2077.58	8.6	310	5.53	392.3	14,559	56.6	1.4 × 10 ¹⁶	9.5 × 10 ¹⁵
2005	0.72	52.8	2268.79	9.3	338	6.25	445.1	16,408	64.0	1.6 × 10 ¹⁶	1.1 × 10 ¹⁶
2006	0.78	57.7	2468.05	10.2	367	7.03	502.8	18,404	72.1	1.8 × 10 ¹⁶	1.2 × 10 ¹⁶
2007	0.84	61.9	2672.02	11.0	395	7.87	564.6	20,548	80.7	2.1 × 10 ¹⁶	1.3 × 10 ¹⁶
2008	0.90	65.7	2874.14	11.7	423	8.78	630.4	22,835	89.8	2.3 × 10 ¹⁶	1.5 × 10 ¹⁶
2009	0.96	69.5	3070.28	12.3	445	9.74	699.9	25,256	99.2	2.5 × 10 ¹⁶	1.6 × 10 ¹⁶
2010	1.01	72.8	3260.92	12.9	475	10.75	772.7	27,800	108.9	2.8 × 10 ¹⁶	1.8 × 10 ¹⁶
Years after shutdown											
100						10.75	772.7	2,610.6	10.7	6.1 × 10 ¹⁵	1.5 × 10 ¹⁵
300						10.75	772.7	100.1	2.0	3.5 × 10 ¹⁵	2.5 × 10 ¹⁵
1,000						10.75	772.7	31.1	0.8	1.5 × 10 ¹⁵	5.6 × 10 ¹⁵
3,000						10.75	772.7	15.9	0.3	7.9 × 10 ¹⁴	2.1 × 10 ¹⁵
10,000						10.75	772.7	10.0	0.2	5.2 × 10 ¹⁴	1.2 × 10 ¹⁵
30,000						10.75	772.7	4.4	0.1	2.4 × 10 ¹⁴	5.4 × 10 ¹⁴
100,000						10.75	772.7	2.3	0.0	4.7 × 10 ¹³	4.3 × 10 ¹⁴
300,000						10.75	772.7	1.6	0.0	2.9 × 10 ¹³	5.2 × 10 ¹⁴
1,000,000						10.75	772.7	0.9	0.0	3.0 × 10 ¹³	3.1 × 10 ¹⁴

^aFrom J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated." Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colorado, July 11-16, 1976. CONF 76-0701.

Table 3. Projected annual accumulation of cladding waste available to a federal repository^a

Year	Annual addition					Accumulation through end of year					
	Volume (10 ³ m ³)	Actinide mass (MT)	Radio- activity (MCi)	Thermal power (MW)	Number of shipments	Volume (10 ³ m ³)	Actinide mass (MT)	Radio- activity (MCi)	Thermal power (MW)	Volume needed for dilution (m ³)	
										Air	Water
1983	0.04	0.24	3.4	0.015	27	0.04	0.24	3	0.01	1.7 × 10 ¹⁶	8.2 × 10 ¹⁰
1984	0.07	0.48	7.0	0.031	54	0.11	0.72	10	0.04	5.1 × 10 ¹⁶	2.4 × 10 ¹¹
1985	0.13	0.87	13.7	0.060	95	0.24	1.59	21	0.10	1.2 × 10 ¹⁷	5.5 × 10 ¹¹
1986	0.15	1.01	17.3	0.074	103	0.39	2.61	35	0.15	2.0 × 10 ¹⁷	9.2 × 10 ¹¹
1987	0.15	1.01	17.7	0.074	98	0.54	3.62	45	0.20	2.8 × 10 ¹⁷	1.3 × 10 ¹²
1988	0.15	1.01	17.3	0.071	99	0.69	4.64	54	0.24	3.5 × 10 ¹⁷	1.6 × 10 ¹²
1989	0.19	1.26	20.8	0.086	125	0.87	5.89	64	0.28	4.4 × 10 ¹⁷	2.0 × 10 ¹²
1990	0.22	1.50	24.4	0.102	150	1.10	7.39	76	0.34	6.0 × 10 ¹⁷	2.4 × 10 ¹²
1991	0.26	1.74	28.1	0.117	175	1.35	9.13	90	0.40	8.5 × 10 ¹⁷	2.9 × 10 ¹²
1992	0.32	2.18	35.0	0.146	218	1.68	11.31	108	0.48	1.2 × 10 ¹⁸	3.5 × 10 ¹²
1993	0.30	2.04	33.7	0.141	205	1.98	13.35	121	0.54	1.4 × 10 ¹⁸	4.1 × 10 ¹²
1994	0.34	2.30	38.4	0.161	231	2.32	15.65	137	0.61	1.7 × 10 ¹⁸	4.7 × 10 ¹²
1995	0.38	2.57	42.6	0.178	257	2.70	18.22	154	0.68	2.1 × 10 ¹⁸	5.4 × 10 ¹²
1996	0.42	2.84	47.5	0.199	283	3.12	21.06	173	0.77	2.5 × 10 ¹⁸	6.1 × 10 ¹²
1997	0.46	3.13	51.9	0.217	311	3.58	24.19	193	0.86	3.1 × 10 ¹⁸	6.9 × 10 ¹²
1998	0.51	3.44	57.2	0.239	341	4.09	27.63	215	0.95	3.7 × 10 ¹⁸	7.8 × 10 ¹²
1999	0.56	3.76	63.0	0.263	373	4.65	31.40	239	1.06	4.3 × 10 ¹⁸	8.8 × 10 ¹²
2000	0.61	4.10	69.1	0.287	407	5.26	35.49	265	1.17	4.9 × 10 ¹⁸	9.8 × 10 ¹²
2001	0.67	4.45	75.2	0.312	441	5.93	39.94	292	1.29	5.6 × 10 ¹⁸	1.1 × 10 ¹³
2002	0.73	4.79	81.9	0.339	477	6.66	44.73	321	1.42	6.4 × 10 ¹⁸	1.2 × 10 ¹³
2003	0.79	5.13	88.9	0.366	512	7.45	49.86	352	1.55	7.2 × 10 ¹⁸	1.3 × 10 ¹³
2004	0.86	5.45	96.1	0.393	546	8.31	55.31	385	1.69	8.0 × 10 ¹⁸	1.5 × 10 ¹³
2005	0.93	5.76	103.6	0.420	580	9.24	61.07	419	1.83	8.9 × 10 ¹⁸	1.6 × 10 ¹³
Years after shutdown											
100						9.24	61.07	24	0.025	4.3 × 10 ¹⁸	1.7 × 10 ¹³
300						9.24	61.07	5	0.012	2.7 × 10 ¹⁸	2.5 × 10 ¹¹
1,000						9.24	61.07	1	0.005	1.5 × 10 ¹⁸	3.7 × 10 ¹⁰
3,000						9.24	61.07	0	0.002	9.4 × 10 ¹⁷	1.4 × 10 ¹⁰
10,000						9.24	61.07	0	0.001	5.8 × 10 ¹⁷	9.2 × 10 ⁹
30,000						9.24	61.07	0	0.000	2.2 × 10 ¹⁷	5.4 × 10 ⁹
100,000						9.24	61.07	0	0.000	3.1 × 10 ¹⁶	4.5 × 10 ⁹
300,000						9.24	61.07	0	0.000	8.3 × 10 ¹⁵	4.3 × 10 ⁹
1,000,000						9.24	61.07	0	0.000	6.0 × 10 ¹⁵	1.8 × 10 ⁹

^aFrom J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated," Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colorado, July 11-16, 1976, CONF 76-0701.

Table 4. Projected annual accumulation of intermediate-level transuranic waste available to a federal repository^a

Year	Annual addition					Accumulation through end of year					
	Volume (10 ³ m ³)	Actinide mass (kg)	Radio- activity (MCi)	Thermal power (kW)	Number of shipments	Volume (10 ³ m ³)	Actinide mass (kg)	Radio- activity (MCi)	Thermal power (kW)	Volume needed for dilution (m ³)	
										Air	Water
1983	0.3	0.8	0.0	0.2	151	0.3	1	0.05	0.2	6.1 × 10 ¹³	2.2 × 10 ¹⁰
1984	0.7	1.8	0.1	0.3	327	1.0	3	0.14	0.5	1.9 × 10 ¹⁴	6.6 × 10 ¹⁰
1985	1.3	3.5	0.2	0.6	628	2.3	6	0.32	1.1	4.4 × 10 ¹⁴	1.5 × 10 ¹¹
1986	1.6	4.3	0.2	0.8	768	4.0	11	0.54	1.8	7.5 × 10 ¹⁴	2.6 × 10 ¹¹
1987	1.4	5.1	0.3	0.9	680	5.4	16	0.76	2.4	1.1 × 10 ¹⁵	3.7 × 10 ¹¹
1988	1.1	3.9	0.2	0.8	519	6.5	20	0.96	3.0	1.4 × 10 ¹⁵	4.7 × 10 ¹¹
1989	1.2	5.5	0.3	1.0	583	7.8	25	1.20	3.8	1.7 × 10 ¹⁵	6.0 × 10 ¹¹
1990	1.4	6.1	0.4	1.2	654	9.2	31	1.48	4.7	2.2 × 10 ¹⁵	7.4 × 10 ¹¹
1991	1.5	10.1	0.4	1.4	719	10.7	41	1.81	5.7	2.7 × 10 ¹⁵	9.2 × 10 ¹¹
1992	1.7	11.5	0.5	1.7	820	12.4	53	2.23	7.0	3.3 × 10 ¹⁵	1.1 × 10 ¹²
1993	1.2	10.5	0.5	1.7	559	13.6	63	2.60	8.1	3.9 × 10 ¹⁵	1.3 × 10 ¹²
1994	1.3	11.8	0.6	1.9	631	15.0	75	3.02	9.4	4.6 × 10 ¹⁵	1.5 × 10 ¹²
1995	1.6	14.2	0.6	2.1	756	16.6	89	3.49	10.9	5.3 × 10 ¹⁵	1.8 × 10 ¹²
1996	1.8	15.9	0.7	2.4	848	18.4	105	4.01	12.5	6.2 × 10 ¹⁵	2.1 × 10 ¹²
1997	2.1	18.6	0.8	2.6	990	20.5	124	4.58	14.3	7.1 × 10 ¹⁵	2.4 × 10 ¹²
1998	2.3	20.2	0.9	2.9	1076	22.7	144	5.21	16.3	8.1 × 10 ¹⁵	2.7 × 10 ¹²
1999	2.5	21.9	0.9	3.1	1167	25.2	166	5.88	18.4	9.2 × 10 ¹⁵	3.1 × 10 ¹²
2000	2.7	23.9	1.0	3.4	1274	27.9	190	6.62	20.7	1.0 × 10 ¹⁶	3.5 × 10 ¹²
2001	3.0	26.7	1.1	3.7	1422	30.9	216	7.41	23.1	1.2 × 10 ¹⁶	3.9 × 10 ¹²
2002	3.3	29.4	1.2	4.0	1568	34.3	246	8.26	25.8	1.3 × 10 ¹⁶	4.3 × 10 ¹²
2003	3.7	32.7	1.3	4.4	1744	38.0	278	9.16	28.6	1.5 × 10 ¹⁶	4.8 × 10 ¹²
2004	4.2	36.7	1.4	4.6	1955	42.1	315	10.11	31.6	1.6 × 10 ¹⁶	5.3 × 10 ¹²
2005	4.6	40.9	1.5	4.9	2179	46.8	356	11.10	34.7	1.8 × 10 ¹⁶	5.9 × 10 ¹²
Years after shutdown											
100						46.8	356	0.93	7.1	1.1 × 10 ¹⁶	5.3 × 10 ¹¹
300						46.8	356	0.12	3.5	8.2 × 10 ¹⁵	2.9 × 10 ¹⁰
1,000						46.8	356	0.05	1.6	5.1 × 10 ¹⁵	1.1 × 10 ¹⁰
3,000						46.8	356	0.02	0.7	3.3 × 10 ¹⁵	4.3 × 10 ⁹
10,000						46.8	356	0.01	0.4	2.1 × 10 ¹⁵	2.7 × 10 ⁹
30,000						46.8	356	0.01	0.2	8.2 × 10 ¹⁴	1.4 × 10 ⁹
100,000						46.8	356	0.00	0.0	1.2 × 10 ¹⁴	1.0 × 10 ⁹
300,000						46.8	356	0.00	0.0	2.8 × 10 ¹³	1.2 × 10 ⁹
1,000,000						46.8	356	0.00	0.0	2.3 × 10 ¹³	7.1 × 10 ⁸

^aFrom J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated." Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colorado, July 11-16, 1976, CONF-76-0701.

Table 5. Projected annual accumulation of low-level transuranic waste available to a federal repository^a

Year	Annual addition					Accumulation through end of year					
	Volume (10 ³ m ³)	Actinide mass (MT)	Radio- activity (MCi)	Thermal power (kW)	Number of shipments	Volume (10 ⁶ m ³)	Actinide mass (MT)	Radio- activity (MCi)	Thermal power (kW)	Volume needed for dilution (m ³)	
										Air	Water
1983	0.1	0.003	0.0	0.0	5	0.000	0.00	0.0	0.0	2.5 × 10 ¹⁶	4.1 × 10 ⁸
1984	0.3	0.007	0.1	0.1	10	0.000	0.01	0.1	0.1	7.9 × 10 ¹⁶	1.3 × 10 ⁹
1985	0.5	0.014	0.1	0.2	19	0.001	0.02	0.2	0.3	1.8 × 10 ¹⁷	3.0 × 10 ⁹
1986	2.9	0.076	0.7	0.9	101	0.004	0.10	1.0	1.2	7.4 × 10 ¹⁷	1.2 × 10 ¹⁰
1987	4.6	0.162	1.6	1.9	162	0.008	0.26	2.5	3.1	1.9 × 10 ¹⁸	3.2 × 10 ¹⁰
1988	6.2	0.219	2.1	2.6	219	0.015	0.48	4.5	5.8	3.5 × 10 ¹⁸	5.9 × 10 ¹⁰
1989	3.5	0.156	1.5	1.8	125	0.018	0.64	5.8	7.8	4.6 × 10 ¹⁸	7.8 × 10 ¹⁰
1990	3.8	0.170	1.7	2.0	136	0.022	0.81	7.2	10.0	5.8 × 10 ¹⁸	9.9 × 10 ¹⁰
1991	4.2	0.281	2.7	3.3	150	0.026	1.09	9.7	13.6	7.8 × 10 ¹⁸	1.3 × 10 ¹¹
1992	4.7	0.312	3.0	3.6	167	0.031	1.40	12.3	17.7	1.0 × 10 ¹⁹	1.7 × 10 ¹¹
1993	4.7	0.415	4.0	4.8	166	0.036	1.81	15.8	23.0	1.3 × 10 ¹⁹	2.2 × 10 ¹¹
1994	5.1	0.452	4.4	5.3	181	0.041	2.27	19.5	29.0	1.6 × 10 ¹⁹	2.8 × 10 ¹¹
1995	5.2	0.455	4.4	5.3	182	0.046	2.72	23.1	35.1	1.9 × 10 ¹⁹	3.4 × 10 ¹¹
1996	5.5	0.482	4.7	5.6	193	0.051	3.20	26.8	41.7	2.3 × 10 ¹⁹	4.0 × 10 ¹¹
1997	6.5	0.577	5.6	6.7	231	0.058	3.78	31.3	49.6	2.7 × 10 ¹⁹	4.7 × 10 ¹¹
1998	6.8	0.600	5.8	7.0	240	0.065	4.38	35.8	57.9	3.1 × 10 ¹⁹	5.5 × 10 ¹¹
1999	7.3	0.641	6.2	7.5	256	0.072	5.02	40.5	66.8	3.5 × 10 ¹⁹	6.3 × 10 ¹¹
2000	8.0	0.709	6.9	8.3	284	0.080	5.73	45.7	76.8	4.0 × 10 ¹⁹	7.2 × 10 ¹¹
2001	9.9	0.783	7.6	9.1	313	0.089	6.51	51.3	87.8	4.6 × 10 ¹⁹	8.2 × 10 ¹¹
2002	9.9	0.875	8.5	10.2	350	0.099	7.39	57.7	100.2	5.1 × 10 ¹⁹	9.3 × 10 ¹¹
2003	11.4	1.011	9.8	11.8	404	0.110	8.40	65.1	114.3	5.8 × 10 ¹⁹	1.1 × 10 ¹²
2004	13.8	1.215	11.8	14.2	486	0.124	9.61	74.1	131.2	6.7 × 10 ¹⁹	1.2 × 10 ¹²
2005	15.8	1.392	13.6	16.2	557	0.140	11.01	84.5	150.5	7.6 × 10 ¹⁹	1.4 × 10 ¹²
Years after shutdown											
100						0.140	11.01	6.3	186.2	4.7 × 10 ¹⁹	1.3 × 10 ¹²
300						0.140	11.01	4.0	130.3	3.3 × 10 ¹⁹	9.4 × 10 ¹¹
1,000						0.140	11.01	1.8	59.5	2.0 × 10 ¹⁹	4.2 × 10 ¹¹
3,000						0.140	11.01	0.8	26.0	1.3 × 10 ¹⁹	1.7 × 10 ¹¹
10,000						0.140	11.01	0.5	15.9	8.5 × 10 ¹⁸	1.0 × 10 ¹¹
30,000						0.140	11.01	0.2	6.3	3.3 × 10 ¹⁸	4.7 × 10 ¹⁰
100,000						0.140	11.01	0.0	1.0	4.4 × 10 ¹⁷	2.2 × 10 ¹⁰
300,000						0.140	11.01	0.0	0.3	6.3 × 10 ¹⁶	2.0 × 10 ¹⁰
1,000,000						0.140	11.01	0.0	0.2	4.8 × 10 ¹⁶	6.4 × 10 ⁹

^aFrom J. O. Blomeke and C. W. Kee, "Projections of Wastes to be Generated." Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colorado, July 11-16 1976. CONF 76-0701.