Dr. 1550-4

I-10068

ONWI-423

Engineered Waste Package System Design Specification

Technical Report

May 1983

Westinghouse Electric Corporation
Advanced Energy Systems Division
P. O. Box 10864
Pittsburgh, PA 15236

MASTER

ONWI
Office of Nuclear Waste Isolation

BATTELLE Project Management Division

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

BIBLIOGRAPHIC DATA

Westinghouse Electric Corporation, 1983. *Engineered Waste Package System Design Specification*, ONWI-423, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

DO NOT MICROFILM
COVER

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A05
Microfiche copy: A01

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ONWI-423
Distribution Category UC-70

ONWI--423

DEB3 91461

Engineered Waste-Package-System Design Specification

Technical Report

May 1983

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

It has been reproduced from the best
available copy to permit the broadest
possible availability.

Westinghouse Electric Corporation
Advanced Energy Systems Division
P. O. Box 10864
Pittsburgh, PA 15236

The content of this report was effective as of November 1982. This report was prepared by Westinghouse Electric Corporation under Subcontract E512-06400 with Battelle Project Management Division, Office of Nuclear Waste Isolation under Contract No. DE-AC06-76RLO1830 and DE-AC02-83CH10140 with the U.S. Department of Energy. This contract was administered by the Battelle Office of Nuclear Waste Isolation.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Dr. 1550-4

I-10068

ONWI-423

Engineered Waste Package System Design Specification

Technical Report

May 1983

**Westinghouse Electric Corporation
Advanced Energy Systems Division
P. O. Box 10864
Pittsburgh, PA 15236**

MASTER

ONWI
Office of Nuclear Waste Isolation

BATTELLE Project Management Division

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

BIBLIOGRAPHIC DATA

Westinghouse Electric Corporation, 1983. *Engineered Waste Package System Design Specification*, ONWI-423, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

DO NOT MICROFILM
COVER

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A05
Microfiche copy: A01

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ONWI-423
Distribution Category UC-70

ONWI--423

DEC 3 01 40 C1

Engineered Waste-Package-System Design Specification

Technical Report

May 1983

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

It has been reproduced from the best available copy to permit the broadest possible availability.

Westinghouse Electric Corporation
Advanced Energy Systems Division
P. O. Box 10864
Pittsburgh, PA 15236

The content of this report was effective as of November 1982. This report was prepared by Westinghouse Electric Corporation under Subcontract E512-06400 with Battelle Project Management Division, Office of Nuclear Waste Isolation under Contract No. DE-AC06-76RLO1830 and DE-AC02-83CH10140 with the U.S. Department of Energy. This contract was administered by the Battelle Office of Nuclear Waste Isolation.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

This report documents the waste package performance requirements and geologic and waste-form data bases used in developing the conceptual designs for waste packages for salt, tuff and basalt geologies. The data base reflects the latest geotechnical information on the geologic media of interest. The parameters or characteristics specified primarily cover spent fuel, defense high-level waste, and commercial high-level waste forms. The specification documents the direction taken during the conceptual design activity. A separate design specification will be developed prior to the start of the preliminary design activity.

PREFACE

The Westinghouse Electric Corporation's Advanced Energy Systems Division has been under contract to the Battelle Project Management Division, Office of Nuclear Waste Isolation (ONWI) to develop waste package conceptual and preliminary designs for salt, tuff and basalt geologies.

Prior to the initiation of conceptual design activities (since completed), ONWI felt that it was necessary to document the bases on which the conceptual design activity was to proceed. This design specification was an outgrowth of that need. This report documents the waste package performance requirements and geologic and waste form data bases used by Westinghouse in developing the conceptual designs. The data base has been updated several times to reflect the latest geotechnical information on the geologic media.

This specification is not intended to supersede any programmatic criteria or specifications which may now be in existence or under development; rather, it is simply a documentation of the direction taken by Westinghouse during the conceptual design activity. This specification will not be used for preliminary design. A separate preliminary design specification will be developed prior to the start of the design activity.

TABLE OF CONTENTS

	<u>Page</u>
1.0 SCOPE	1
2.0 PROGRAM DOCUMENTS	3
2.1 APPLICABLE DOCUMENTS	3
2.2 SOURCE DOCUMENTS	3
2.3 REFERENCED DOCUMENTS	4
3.0 REQUIREMENTS	5
3.1 PERFORMANCE	5
3.1.1 Functional Characteristics	5
3.1.1.1 Primary Performance Characteristics.	5
3.1.1.2 Secondary Performance Characteristics.	8
3.1.2 Operability	9
3.1.2.1 Reliability	9
3.1.2.2 Maintainability	10
3.1.2.3 Useful Life	10
3.1.2.4 Environment	10
3.1.2.5 Transportability and Handling	10
3.1.2.6 Standardization	11
3.1.2.7 Safety	12
3.2 ENGINEERED WASTE PACKAGE DEFINITION	12
3.2.1 Component Definition	12
3.2.1.1 Waste Form	12
3.2.1.2 Waste Package Components	13
3.2.2 Interface Requirements	14
3.3 DESIGN AND CONSTRUCTION.	15
3.3.1 General Design Features	15
3.3.2 Codes and Standards	16
3.3.3 Materials, Parts and Processes	16
3.3.4 Corrosion Resistance	17
3.3.5 Interchangeability	17
3.3.6 Identification and Marking	17
3.3.7 Storage	17
4.0 APPENDIX	18
4.1 TABLES	18
4.2 TABLE REFERENCES AND NOTES	79

1.0 SCOPE

This specification document defines the performance, design and qualification requirements for the Engineered Waste Package System to be used in the geological disposal of high level and transuranic radioactive waste. The scope of this specification encompasses various waste types each of which may be emplaced in different geologies. The nuclear waste types are (1) spent fuel, (2) defense high level reprocessing waste, (3) commercial high level reprocessing waste, and (4) various transuranic waste types. The host rocks include (1) salt, (2) basalt, (3) tuff, and (4) granite. Values and limits for the various parameters of the waste types and host rocks that are intended to be used in the conceptual design effort are established.

The Engineered Waste Package System includes the waste form and all components that enclose the waste form out to the near field host rock. The Engineered Waste Package System components may include a waste form canister, stabilizers within the canister, overpacks, fillers, emplacement hole liners or sleeves, coatings, and any emplacement material.

The functional performance of the engineered barrier design will be to ensure containment of the waste form for a period of 1000 years after geologic repository decommissioning. The waste form degradation or leachability rates will be determined under separate non-design related studies to meet the longer term requirements, utilizing simulated in-situ test conditions created by products of degradation from the engineered barriers and expected geological conditions.

Sections of this specification document dealing with geological, waste form, and transportation conditions are included for completeness and define the values being used in the design process. It is the responsibility of the waste form and geological system developers to ensure that complete and most recent requirements are defined to the appropriate interface coordination group (ICG). The ICG will ensure these values are incorporated into this specification.

The maturity of the specification document at this time is such that the parameters or characteristics specified herein primarily cover spent fuel, defense high level, and commercial high level waste forms, and host geologies consisting of salt, basalt, tuff, or granite. These requirements were developed from information that is presently available, some of which is only in draft form. In some cases, requirements between several source documents were different or conflicting, and decisions had to be made to establish the criterion or design requirement based on judgement as to what the requirement most reasonably might be. This specification document, therefore, will be updated and re-issued periodically to incorporate the requirements for the other waste types and host rocks as they are developed, and any needed revisions to the requirements specified herein.

2.0 PROGRAM DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents form a part of this specification document. If conflict is found between the contained information in this specification document and these documents, the documents shall take precedence.

- 10CFR60 - Technical Criteria for Regulating Geologic High Level Radioactive Waste - Federal Register/Vol. 45, No. 94/Tuesday, May 13, 1980/Advanced Notice of Rulemaking and Federal Register/Vol. 46, No. 130/Wednesday, July 8, 1981/Proposed Rules.
- 40CFR191 - Environmental Radiation and Protection Standards for Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Waste - Working Draft No. 8/December 10, 1979.

2.2 SOURCE DOCUMENTS

The following documents have served as a source for developing the Engineered Waste Package System requirements. The Paragraph 2.1 documents of this specification document shall take precedence over the source documents if a conflict exists.

- DOE/NWTS33(1) - NWTS Program Criteria for Mined Geologic Disposal of Nuclear Wastes - Program Objectives, Functional Requirements, and System Performance Criteria.
- DOE/NWTS33(2) - NWTS Program Criteria for Mined Geologic Disposal of Nuclear Wastes - Site Performance Criteria (Feb. 1981)
- DOE/NWTS33(3) - NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste - Repository Performance Criteria.
- DOE/NWTS33(4a) - NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste - Functional Requirements and Performance Criteria for Waste Packages for Solidified High-Level Waste and Spent Fuel.

2.3 REFERENCED DOCUMENTS

The following documents form a part of this specification document to the extent specified herein. In the event of conflict, the detail requirements as specified herein or as required by the Paragraph 2.1 documents shall take precedence.

10CFR20	-	Standards for Protection Against Radiation
10CFR50	-	Appendix B - Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants
10CFR71	-	Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions
49CFR173	-	Shippers - General Requirements for Shipments and Packagings
30CFR57	-	Health and Safety Standards - Metal and Non-Metallic Underground Mines

3.0 REQUIREMENTS

3.1 PERFORMANCE

3.1.1 Functional Characteristics

3.1.1.1 Primary Performance Characteristics

3.1.1.1.1 - The engineered waste package consisting of the waste form and ancillary engineered enclosures must provide reasonable assurance that radionuclides will be contained for at least the first 1000 years after decommissioning and as long thereafter as is reasonably achievable given expected processes and events including conditions resulting from the presence of the waste package. This shall include the "presence of water/brine," if such presence is part of the expected conditions. Human intrusion effects are not expected or considered during this time period.

The phrase "presence of water/brine" shall be interpreted to mean the following. The water available for reaction with the engineered waste package will be the sum of the natural (pre-excavation) moisture content of the host rock and the water which migrates to the engineered waste package due to effects of the emplacement itself (as by thermal gradient-driven brine migration). The only continuing movement of this water will be due to thermal gradients, natural in situ movement at pre-excavation conditions or in the case of salt, brine migration. Except for the repository operation period and for a brief period following repository closure and decommissioning, it is assumed that this water will be in chemical equilibrium with the surrounding geology. The Paragraph 2.1 Program Document, 10CFR60, Paragraph 122(c)(1)(ii)(b) favors sites with little or no ground-water circulation within the host rock. This, coupled with the statement in Paragraph 122(c)(2)(iii) of this same document, leads to the assumption that only sites in which net water flow in the host rock, prior to excavation, is very low, will be selected for geologic repositories.

3.1.1.1.2 - Starting 1000 years after decommissioning of the geologic repository operations area, and extending to 10,000 years the "radionuclides present will be released from the engineered waste package at an annual rate as low as reasonably achievable and no greater than that shown in

Table 1 to assure that an annual rate of no greater than one part in one hundred thousand of the maximum total activity for any radionuclide present in high level waste (HLW) within the underground facility after 1000 years after decommissioning is released to the accessible environment" assuming expected processes and events as well as credible but "unlikely events."

The phrase "radionuclides present will be released from the engineered waste package at an annual rate as low as reasonably achievable and no greater than that shown in Table 1 to assure that an annual rate of no greater than one part in one hundred thousand of the total activity present in high level waste (HLW) within the underground facility 1000 years after decommissioning is released to the accessible environment" shall be interpreted to mean the following for the engineered waste package. Until allocated differently a radionuclide release of one part in one hundred thousand shall be used for the engineered waste package requirement. In predicting definitive performance, engineered waste package components other than the waste form which were not included to assist the waste form are to be taken as completely ineffective during this time. Unless it can be reasonably shown by analysis or testing that they would be effective.

The phrase "unlikely events" shall be interpreted to mean an event having a probability of less than 10^{-4} per 10,000 years and is taken here as forms of human intrusion (e.g., solution mining in salt, or a well in hard rock) resulting in a waste package condition described as follows. In the salt host rock, the remaining intact engineered waste package component, that is, the waste form, is surrounded by non-dissolved solids and saturated brine. The brine is stagnant except for thermally induced movement with the time of initiation being variable. In all other host rocks, the liquid is saturated with either solubility or leaching governing dissolution of the waste form.

3.1.1.1.3 - Starting at decommissioning, and extending to 10,000 years, radionuclides present in transuranic (TRU) waste will be released from the engineered waste package at an annual rate as low as reasonably achievable and no greater than that shown in the right-hand column of Table 2 to assure that an annual rate no greater than one part in one hundred thousand of the

total activity present in TRU waste at the time of decommissioning is released to the accessible environment assuming expected processes and events as well as credible but "unlikely events."

Interpretation of the phrase "unlikely events" is the same as given in Paragraph 3.1.1.1.2 for HLW.

The TRU waste form is anticipated to be similar to defense HLW but with a reduced activity level. The requirements of the Paragraph 2.1 Program Document, 10CFR60, Paragraph 133, preclude the direct packaging for geologic repository emplacement of the TRU waste as it is generated. The nature of TRU waste, on hand and being temporarily stored, is quite variable. It contains, in part, process sludge, equipment, filters, metals, rubber materials, wood, and many other materials containing greater than 10 nCi of long-lived alpha-emitting radionuclides per gram of waste. Much of this waste is currently stored in 55 gallon steel drums but in many cases the exact nature of the contents is unknown. Because of the concerns for combustible and gas generating characteristics of much of this TRU waste, consideration is now being given to incineration of these wastes followed by incorporation of the ash into several of the matrices under consideration for HLW, e.g., glass, concrete, ceramics, etc.

3.1.1.1.4 - The portion of the engineered waste package containing the waste form, which is brought down from the surface, hereafter referred to as the RETRIEVABLE PACKAGE, shall be retrievable intact and comply with 10CFR20 exposure to workers as it applies to nuclear fuel facilities for a period to be specified in 10CFR60. For conservatism in engineered waste package design, it will be assumed that in host rocks prone to creep that lithostatic pressure is re-established during the period prior to retrieval (observation period). In other host rocks, hydrostatic or other design pressure may be imposed on the engineered waste package during the observation period. Retrievability is not required after geologic repository decommissioning. Retrieval of the retrievable package shall be accomplished in about the same period of time as that used during its emplacement.

For engineered waste package design purposes, component selection will be based on a maximum lifetime requirement of 150 years relative to retrievability.

3.1.1.1.5 - The engineered waste package shall be designed in concert with the geologic repository to comply with the applicable federal, state and local laws, statutes and regulations necessary to ensure that the entire facility meets the licensing requirements of the Nuclear Regulatory Commission. The federal requirements common to all commercial waste geologic repositories are stated in the applicable documents specified in Paragraph 2.1. State and local laws shall be assumed to be no more severe than the federal ones.

3.1.1.2 Secondary Performance Characteristics

3.1.1.2.1 - The engineered waste package when emplaced and in conjunction with the geologic repository design prior to decommissioning shall comply with 10CFR20 exposure to workers as it applies to nuclear fuel facilities.

3.1.1.2.2 - The engineered waste package when emplaced and in conjunction with the geologic repository design prior to decommissioning shall comply with 40CFR191 for exposures to the general public.

3.1.1.2.3 - The containerized waste and retrievable package design shall be standardized to the extent practical to allow for its potential use at all geologic repositories and to ensure its compatibility with all geologic repository handling facilities.

3.1.1.2.4 - Each retrievable package design shall have unique identification for each container that shall provide matching of the container with its permanent written records, legible at least to the end of the retrieval period.

3.1.1.2.5 - The waste form and retrievable package design shall assure that $K_{eff} \leq 0.95$ and that a nuclear criticality accident cannot occur unless at least two unlikely independent and concurrent or sequential changes have occurred.

3.1.1.2.6 - The engineered waste package design shall utilize a system of components such that the failure of any one engineered waste package component shall not cause loss of function of any other component. A component may have more than one member, such as an overpack and an overpack reinforcement which together serve one or more waste package functions.

3.1.2 Operability

3.1.2.1 Reliability

3.1.2.1.1 - An engineered waste package design which incorporates components which perform multiple or redundant functions shall be such that no common mode failures can occur under expected environments.

3.1.2.1.2 - The engineered waste package design in addition to meeting all functional requirements shall provide reasonable assurance that the waste form will not be exposed for at least 1000 years after decommissioning when the barriers are exposed sequentially to the worst expected environments resulting at the initial time of exposure of each barrier to the external conditions.

The engineered waste package design and the waste package component fabrication processes, installation procedures, and inspection methods shall be such as to provide reasonable assurance that the number and type of credible, undetected defects in critical package components and materials will not result in a rate of radionuclide release from defected packages during the containment period (1,000 years following decommissioning) that exceeds the acceptable rate of radionuclide release during the post-containment period as specified in Section 3.1.1.1.2.

3.1.2.1.3 - For design information, the nominal best available waste form and host rock parameter values as defined in the Paragraph 6.1 tables will be used except that structural design shall be performed using standard practices. The design basis of 1000 years after decommissioning is considered to incorporate sufficient margin to adequately accommodate uncertainties in these values when applying 10CFR60-111(c)(1) and 132(a)(3)(ii) conditions.

3.1.2.2 Maintainability

No specific maintainability provisions are required for the engineered waste package other than the provision to retrieve as stated in Paragraph 3.1.1.1.4.

3.1.2.3 Useful Life

3.1.2.3.1 - Retrievability of the retrievable package shall be required in accordance with Paragraph 3.1.1.1.4.

3.1.2.3.2 - The engineered waste package shall provide reasonable assurance of containment of all radionuclides for at least 1,000 years after decommissioning.

3.1.2.3.3 - The remaining intact engineered waste package components in conjunction with the geologic repository design and the geologic structure shall limit release of radionuclides to the accessible environment for 10,000 years after decommissioning.

3.1.2.4 Environment

3.1.2.4.1 - The nominal expected geologic repository environment conditions utilized as engineered waste package design parameters are defined in Table 3.

3.1.2.5 Transportability and Handling

3.1.2.5.1 - The retrievable package and the canister with its enclosed waste form alone shall be capable of transportation by conventional rail and truck systems in conjunction with suitable shipping casks. In conjunction with the shipping casks, transportation must comply with applicable requirements of 10CFR71 and 49CFR173.

For design information, existing shipping cask characteristics are defined in Table 4. Shipping casks are expected to be designed in the future having larger and/or additional internal cavities than those shown in Table 4.

3.1.2.5.2 - The retrievable package and the canister with its enclosed waste form alone shall be suitable for lifting, transferring and orienting both on and off the geologic repository site and shall meet the Paragraph 3.1.1.1.4 requirement. Appropriate attachment features, of a single type for at least each waste form type, shall be provided for in the retrievable package design to assure positive engagement with handling systems that are fail-safe-upon- malfunction. Appropriate retrievable package handling features shall be provided to interface with all facilities involved in retrievable package handling and shipping operations.

3.1.2.5.3 - The retrievable package and the canister with its enclosed waste form in conjunction with a suitable shipping cask or packaging shall be designed to withstand the Table 5 transportation environment without degradation of component performance. The handling environment will not be more severe than the transportation environment.

3.1.2.5.4 - The canistered waste and the retrievable package shall be capable of being handled and transferred on the geologic repository site and between the surface and subsurface emplacement.

3.1.2.6 Standardization

3.1.2.6.1 - To the extent practical, the retrievable package shall be standardized as to geometry, dimensions, weight and heat content for all waste form types for use in all geologic repositories. The retrievable package should be standardized for a single waste form type for use in all geologic repositories.

3.1.2.6.2 - Provisions for handling and assembly of the canistered waste form and the retrievable package shall be standardized to the extent practical for all waste form types and all geologic repositories. The handling and assembly for each waste form type should be standardized.

3.1.2.7 Safety

3.1.2.7.1 - All engineered waste package component assembly and handling operations and associated equipment shall be designed to meet the Paragraph 3.1.1.2.5 nuclear criticality performance requirements.

3.1.2.7.2 - Elements or subassemblies of the engineered waste package shall not be capable of initiating or sustaining combustion under reasonably expected conditions and events shown in Table 6.

3.1.2.7.3 - The retrievable package and the canister with its enclosed waste form alone shall be capable of a free vertical fall onto a non-yielding surface for a distance of 1.2 times the retrievable package dimension in the direction of fall without release of radionuclides or loss of handling capability.

3.1.2.7.4 - All aspects of the engineered waste package assembly and handling operations in conjunction with the handling systems and geologic repository facilities design shall comply with applicable portions of 10CFR20 and 40CFR191 relative to personnel radiation exposure.

3.1.2.7.5 - The design of the engineered waste package as it relates to geologic repository industrial safety shall conform to the requirement of 30CFR57, Subparts D, E, and N, as applicable.

3.2 ENGINEERED WASTE PACKAGE DEFINITION

3.2.1 Component Definition

3.2.1.1 Waste form - The characteristics of the waste forms to be packaged for emplacement for: (1) Spent Fuel Form Numbers 1 and 2 are presented in Tables 7 and 8, (2) Commercial High Level Waste is presented in Table 9, (3) Defense High Level Waste Form Numbers 1, 2 and 3 are presented in Tables 10, 11, and 12, and (4) Transuranic Waste Form Numbers 1, 2 and 3 are presented in Tables 13, 14 and 15. Tables 7A and 7B provide additional data for Spent Fuel Form Number 1.

3.2.1.2 Waste Package Components - The engineered waste package is conceived to consist of the waste form, described in Paragraph 3.2.1.1, and one or more of the following components: (a) stabilizer, (b) canister, (c) overpack, (d) sleeve, (e) backfill, (f) buffer materials, and (g) filler materials.

The stabilizer is a material that can serve to immobilize the radionuclides and/or fine particulates and resist degradation of the waste form. Also, it can aid in criticality control, heat transfer and mechanical support. The stabilizer is usually considered to be contained within the waste form canister.

The canister is the container that encloses the waste form and stabilizer. It provides a principle containment of contamination to facilitate handling and transportation and to protect the waste form during geologic repository operations. It may serve as one of the barriers for radionuclide containment.

The overpack is any additional receptacle, box or other structure used as an integral part of the engineered waste package and is used to enclose the canister for purposes of providing an additional barrier for radionuclide containment as required to meet acceptance criteria.

The sleeve is used, when required, to assure clearance for the retrievable package to facilitate its removal during the retrieval period. It provides structural support against geologic pressure forces and may also serve the function of a barrier for radionuclide containment.

Backfill is the material contained between the other engineered waste package components and the host rock. It can serve to facilitate heat transfer, load transfer and compatibility of the other engineered waste package components with the host rock. It may also serve as one of the barriers for radionuclide containment and a sorptive medium for radionuclide release.

Buffer is the material used to facilitate conditioning of ground water, immobilization of radionuclides and compatibility of materials.

The filler is any material used to fill space between other components of the engineered waste package and may or may not have another specified function.

3.2.2 Interface Requirements

3.2.2.1 - The engineered waste package(s) must be interfaced with the waste form relative to the waste form characteristics. These characteristics are defined in Tables 7 thru 15, inclusive.

3.2.2.2 - The engineered waste package interfaces with the host rock relative to the host rock characteristics. These characteristics are defined in Table 3.

3.2.2.3 - The maximum acceptable thermal levels for the host rock are defined in Table 16.

3.2.2.4 - The canister design, including stabilizer if applicable, must be interfaced with the waste form as to configuration and for assembly/disassembly operations at the treat and package facility. The canister must also be interfaced with the shipping cask design for transportation relative to loads, configuration, heat release, accountability, and shipping cask safety analysis. The canister design must be interfaced with storage facilities at the treat and package facility and at the geologic repository. It must also be interfaced with operations at the geologic repository.

The canistered waste form configuration must observe the following interface requirements:

(a) Shipping cask characteristics per Table 4.

(b) For spent fuel it must be capable of accepting PWR and BWR assemblies per Table 7.

3.2.2.5 - The retrievable package must observe the following interface requirements:

- (a) Shipping cask characteristics per Table 4.
- (b) Geometry constraints for handling in the geologic repository excavation similar to those in Table 17.

3.2.2.6 - Monitoring shall be required of a statistically significant number of engineered waste packages in the geologic repository during repository operational lifetime. The instrumentation required for this function must be interfaced such that it will not impose additional restraints upon the engineered waste package design.

3.3 DESIGN AND CONSTRUCTION

3.3.1 General Design Features

The engineered waste package shall provide the following design features and characteristics:

- (a) *Functionally independent multi-barrier configuration including, where necessary, a portion which can be pre-placed in the repository to receive the retrievable package.*

A functionally independent multi-barrier configuration is defined as one that consists of three or more engineered waste package system components each of whose primary functions are unrelated. Each component can also serve as a barrier for radionuclide containment. One of the components shall be the waste form.

- (b) Component fabrication and assembly operations shall be amenable to mass production and, where applicable, to remote operations.
- (c) The retrievable package shall be, to the extent practical, a standardized unit capable of installation in all geologic repositories, and shall be of a configuration capable of effective decontamination and provide for removal of the waste form.

- (d) The retrievable package configuration shall provide for positive grappling to insure safety.

3.3.2 Codes and Standards

The engineered waste package shall be designed, fabricated and tested in accordance with generally recognized codes and standards except in the cases where it can be shown that this would result in hardship or unusual difficulties without a compensating increase in the level of quality and safety. Acceptable codes and standards are presented in Table 18.

3.3.3 Materials, Parts and Processes

3.3.3.1 - Materials shall be excluded, or used in insignificant quantities for packaging waste, which exhibit characteristics of combustibility, gas generation, enhanced radiological transport or chemical toxicity that could present undue hazards to operating personnel. For purposes of combustibility, the requirements of Table 6 apply.

3.3.3.2 - Materials shall be excluded for packaging waste where required quantities would represent more than 1% of the U.S. available reserves or have a redeemable value in excess of ten dollars per pound (in significant quantities) at 1980 dollars.

3.3.3.3 - Materials utilized in the construction of the retrievable package shall be identifiable by an ASTM or other recognized standard. Special or proprietary materials shall not be used without sufficient documentation for assurance that the material is suitable for its intended use.

3.3.3.4 - To the extent practical, materials, parts and processes which are state-of-the-art shall be used for the engineered waste package.

3.3.4 Corrosion Resistance

3.3.4.1 - Dissimilar materials shall not be used in the design in such a manner as to accelerate corrosion of any of the engineered waste package components.

3.3.4.2 - Assembly procedures shall be performed with processes and methods that do not compromise the corrosion resistance of materials or coatings.

3.3.5 Interchangeability

3.3.5.1 - All components of a given engineered waste package design with the same part numbers shall be physically and functionally interchangeable.

3.3.6 Identification and Marking

3.3.6.1 - The canister and the retrievable package shall have provision for unique identification. The canister identification shall be applied at or prior to the time of loading with the waste form to assure traceability from the first operation. The identification of the retrievable package shall be performed at or prior to the time of assembly to assure traceability from the first operation. Identification shall not degrade the functioning of the canister and retrievable package in containment of the radionuclides. The identification of the retrievable package shall also provide quick and easy identification for control and traceability throughout the retrieval period. Retention of serialization and identification must be provided for in the event repair or modification is performed.

The method of identification shall not interfere with operations, and shall be resistant to wear and tampering during the retrieval period.

3.3.7 Storage

The individual components, excluding the waste form and backfill, of the engineered waste package shall be suitable for storage in the environmental conditions defined in Table 19. Any special storage requirements shall be specified by the engineered waste package designer.

4.0 APPENDIX

4.1 TABLES

Table 1	- Cumulative Releases to the Accessible Environment for the Period 1,000 to 10,000 Years after Decommissioning - High Level Waste
Table 2	- Cumulative Releases to the Accessible Environment for the Period from Decommissioning to 10,000 Years - Transuranic Waste
Table 3A	- Expected Geotechnical Parameters for Geologic Repositories in Salt
Table 3A-1	- Representative Brines/Solutions for Salt Repositories
Table 3A-2	- Salt Thermal Conductivity
Table 3B	- Expected Geotechnical Parameters for Geologic Repositories in Basalt
Table 3B-1	- Basalt Nuclide Sorptive Capacity
Table 3B-2	- Basalt Composition
Table 3B-3	- Basalt Groundwater Composition
Table 3C	- Expected Geotechnical Parameters for Geologic Repositories in Tuff
Table 3C-1	- Mineralogy of Reference Welded Tuff
Table 3C-2	- Major Element Bulk Composition for Reference Welded Tuff
Table 3C-3	- Reference Groundwater Composition for Tuff Repositories
Table 3D	- Expected Geotechnical Parameters for Geologic Repositories in Granite
Table 3D-1	- Granite Mineral Constituents
Table 4	- Shipping Casks for Current Generation LWR Spent Fuel
Table 5	- Transportation Imposed Loads on the Canister Enclosed Waste Form or Retrievable Package
Table 6	- Reasonable Expected Conditions Under which Combustion must not be Initiated or Sustained by the Waste Package
Table 7	- Waste Form Characteristics - Spent Fuel Form Number 1
Figure 7-1	- Waste Form Characteristics - Spent Fuel Number 1
Table 7-1	- Characteristics of Typical LWR Fuel Assemblies
Table 7-2	- Spent Fuel Assembly Thermal Levels and Radioactivity Content
Table 8	- Waste Form Characteristics - Spent Fuel Form Number 2
Table 8-1	- Physical Characteristics of Typical BWR Fuel Assemblies
Table 8-2	- Physical Characteristics of PWR Assemblies
Table 8-3	- Physical Characteristics of PWR Assemblies
Table 8-4	- Spent Fuel (Form 2) Heat Generation Rates
Table 9	- Waste Form Characteristics - Commercial High Level Waste
Table 9-1	- CHLW Heat Generation Rate
Table 9-2	- CHLW Composition
Table 10	- Waste Form Characteristics - Defense High Level Waste Form Number 1
Table 10-1	- DHLW (Form 1) Thermal Conductivity
Table 10-2	- DHLW (Form 1) Heat Capacity
Table 10-3	- DHLW (Form 1) Density
Table 10-4	- DHLW (Form 1) Heat Generation Rate
Table 10-5	- DHLW Glass Composition
Table 11	- Waste Form Characteristics - Defense High Level Waste Form Number 2
Table 11-1	- Canister Heat Generation

4.1 TABLES (Continued)

Table 11-2	- Radiation from Canister of Stage 1/Stage 2 Ceramic Waste
Table 11-3	- Isotopic Content of Stage 1/2 Ceramic Waste Form
Table 11-4	- SRP Ceramic Waste Form Phase Composition
Table 11-5	- Feed Composition for SRP Ceramic Waste Form Oxide Basis
Table 11-6	- Leach Rates for Synroc D via MCC-1 and MCC-2 28 Day Leach Tests ²
Table 12	- Waste Form Characteristics - Defense High Level Waste Form Number 3
Table 13	- Waste Form Characteristics - Transuranic Waste Form Number 1
Table 14	- Waste Form Characteristics - Transuranic Waste Form Number 2
Table 15	- Waste Form Characteristics - Transuranic Waste Form Number 3
Table 16-A	- Reference Repository Thermal Characteristics - Salt
Table 16-B	- Reference Repository Thermal Characteristics - Basalt
Table 16-C	- Reference Repository Thermal Characteristics - Tuff
Table 16-D	- Reference Repository Thermal Characteristics - Granite
Table 17-A	- Repository Excavation Geometry Constraints on Retrievable Package Design - Salt
Table 17-B	- Repository Excavation Geometry Constraints on Retrievable Package Design - Basalt
Table 17-C	- Repository Excavation Geometry Constraints on Retrievable Package Design - Tuff
Table 17-D	- Repository Excavation Geometry Constraints on Retrievable Package Design - Granite
Table 18	- Acceptable Codes and Standards
Table 19	- Interim Storage Environmental Conditions

TABLE 1

CUMULATIVE RELEASES TO THE ACCESSIBLE ENVIRONMENT FOR THE PERIOD
1000 TO 10,000 YEARS AFTER DECOMMISSIONING - HIGH LEVEL WASTE

RELEASE LIMIT	
RADIONUCLIDE	ACCESSIBLE ⁽¹⁾ ENVIRONMENT (CURIES/1000MTHM)
Americium-241	10
Americium-243	4
Carbon-14	200
Cesium-135	2000
Cesium-137	500
Neptunium-237	20
Plutonium-238	400
Plutonium-239	100
Plutonium-240	100
Plutonium-242	100
Radium-226	3
Strontium-90	80
Technetium-99	2000
Tin-126	80
Any other Alpha emitting radionuclide	10
Any other radio- nuclide which does not emit Alpha particles	500

(1) Reference Draft 40CFR191 Appendix A

TABLE 2
CUMULATIVE RELEASES TO THE ACCESSIBLE ENVIRONMENT FOR THE PERIOD
FROM DECOMMISSIONING TO 10,000 YEARS - TRANSURANIC WASTE

RADIONUCLIDE	RELEASE LIMIT	
	ACCESSIBLE ⁽¹⁾ ENVIRONMENT (curies)	ALLOCATION TO A WASTE PACKAGE ⁽²⁾
Americium-241	2	One part in
Americium-243	1	10 ⁴ parts/
Neptunium-237	2	year radio-
Plutonium-238	50	nuclide
Plutonium-239	50	inventory at
Plutonium-240	50	1000 years after
Plutonium-242	50	decommissioning out
Any Other Alpha-	5	to 10,000 years
Emitting Radionuclide		after decommissioning

(1) Reference Draft 40CFR191 Appendix A for total geologic repository cumulative release.

(2) DOE/NWTS 33(4)

TABLE 3A

EXPECTED GEOTECHNICAL PARAMETERS
FOR GEOLOGIC REPOSITORIES IN SALT

<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>	<u>COMMENT</u>	<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>	
Depth	600 m			Rock Fabric	May be amorphous or recrystallized.		
Design Basis Earthquake	0.3 g	3-2		Interstitial Gas	Frequent impurities. N ₂ , O ₂ , HF, CO ₂ , SO ₂	3-6	
In Situ Pressure				Mineral Constituents	>90% NaCl	3-17	
Lithostatic	16.2 MPa	Calc.	Calculated as per Ref. 3-3 and 3-4	Water Constituents	Impurities include clay, anhydrite, shale, others		
Hydrostatic	6.0 MPa	Calc.			See Table 3A-1		
Maximum Design Pressure	Maximum design pressure equals lithostatic plus the pressures created by the use of backfill materials and by thermal transients			Compressive Strength	30 MPa	3-5	
Fractures - Spacing	None Reported			Tensile Strength	1-3 MPa	3-8	
Density	2.17 g/cm ³	3-20		Young's Modulus	7 GPa	3-5	
Porosity (Volume)	1.4 - 10%	3-8		Poisson's Ratio	0.4	3-5	
Water Content (Weight)	1.5%	Project Assumption		Creep	0.65 cm/year	3-7	At 25°C
Permeability	10 ⁻¹⁵ to 10 ⁻² md	3-8		Thermal Conductivity	See Table 3A-2	3-20	
Sorptive Capacity - H ₂ O	Neg - 1.0%	3-6		Thermal Expansion	40X10 ⁻⁶ °C ⁻¹	3-5	
Sorptive Capacity Nuclides				Specific Heat Capacity	0.85 kJ/kgK	3-20	
Sr	0.1 ml/g	3-5					
Cs	0.1 ml/g	3-5					
Ba	0.1 ml/g	3-5					
Eu	0.1 ml/g	3-5					
Pu	0.1 ml/g	3-5					
Am	0.1 ml/g	3-5					
Sorptive Capacity - Cation Exchange Capacity	None Reported						

TABLE 3A-1
REPRESENTATIVE BRINES/SOLUTIONS FOR SALT REPOSITORIES*

	Brine "A"** (mg/liter) (+ 3%)	Brine "B"*** (mg/liter) (+ 3%)
Na ⁺	42,000	115,000
K ⁺	30,000	15
Mg ⁺⁺	35,000	10
Ca ⁺⁺	600	900
Fe ⁺⁺⁺	2	2
Sr ⁺⁺	5	15
Li ⁺	20	--
Rb ⁺	20	1
Cs ⁺	1	1
Cl ⁻	190,000	175,000
SO ₄ ⁻⁻	3,500	3,500
B (BO ₃ ⁻⁻⁻⁻)	1,200	10
HCO ₃ ⁻	700	10
Br ⁻	400	400
I ⁻	10	10
pH (adjusted)	6.5	6.5
specific gravity	1.2	1.2

*Reference 3-6

**Inclusion Brine

***Dissolution Brine

TABLE 3A-2
SALT THERMAL CONDUCTIVITY*

<u>Temperature (°C)</u>	<u>Thermal Conductivity (W/mK)</u>
0	6.11
50	5.02
100	4.20
150	3.60
200	3.11
250	2.77
300	2.49
350	2.30

*Reference 3-20

TABLE 3B
EXPECTED GEOTECHNICAL PARAMETERS
FOR GEOLOGIC REPOSITORIES IN BASALT

<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>	<u>COMMENT</u>	<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>	<u>COMMENT</u>
Depth	1128 m			Rock Fabric	Generally fine-grained with frequent joints	3-8	
Design Basis Earthquake	0.23 g	3-9		Interstitial Gas	None Reported		
In Situ Pressure				Mineral Constituents	See Table 3B-2		
Lithostatic	29 MPa	3-9		Water Constituents	See Table 3B-3		
Hydrostatic	11.34 MPa	3-31		Compressive Strength	189 MPa	3-9	
Maximum Design Pressure	Maximum design pressure is hydrostatic plus any additional pressure created by the use of backfill materials or by thermal transients			Tensile Strength	14.8 MPa	3-9	
25 Fractures - Spacing	10 cm	3-9		Young's Modulus	67.6 GPa	3-9	
Density	2.77 g/cm ³			Poisson's Ratio	0.25	3-9	
Porosity	0.1%	3-30		Creep	None Reported		
Hydraulic Conductivity	3.2 x 10 ⁻¹⁶ m/s	3-30		Thermal Conductivity	2.16 + 0.00075T		T is temp in °C
Regional Hydraulic Gradient	10 ⁻³ m/m	3-30		Thermal Expansion	6.33 x 10 ⁻⁶ °C ⁻¹		
Sorptive Capacity Nuclides	See Table 3B-1			Specific Heat Capacity	0.93 + 0.234x10 ⁻³ T		T is temp in °C
Sorptive Capacity	1.7 meg/100g	3-9		Ambient Rock Temperature	59°C		
Cation Exchange Capacity							

TABLE 3B-1
BASALT NUCLIDE SORPTIVE CAPACITY

The data below is from REF. 3-11.

<u>Sorption Coefficients (K_d)</u>			
<u>Element</u>	<u>Measured K_d</u>	<u>Element</u>	<u>Estimated K_d</u>
Cs	70	H	0
Sr	60	C	0
Se	0	Kr	0
I	0	Sm	100
Tc	0	Cm	20
Np	3	Pa	50
Ra	50	Th	50
U	0	Ac	10
Pu	50	Zr	10
Am	20	Pd	10
		Cd	10
		Sn	10
		Ho	10
		Pb	10

TABLE 3B-2
BASALT COMPOSITION*

<u>Constituent</u>	<u>Weight %</u>
SiO ₂	55.29
Al ₂ O ₃	14.49
FeO**	11.58
MgO	3.97
CaO	7.58
Na ₂ O	3.04
K ₂ O	1.69
TiO ₂	2.10
P ₂ O ₅	0.37
MnO	0.19

*Reference 3-9

**FeO + Fe₂O₃ reported as FeO

TABLE 3B-3
BASALT GROUNDWATER COMPOSITION*

Chemical Species	Composition	
	(mg/l)	(meq/l)
Na ⁺	363	15.8
K ⁺	3.43	0.0877
Ca ⁺²	2.76	0.138
Mg ⁺²	0.032	3.1 x 10 ⁻⁴
Total Cation Equivalence		16.00
Cl ⁻	310	8.75
SO ₄ ⁻²	173	3.604
F ⁻	33.4	1.76
Alkalinity** (as HCO ₃ ⁻)		1.82
Total Anion Equivalence		16.06

*REF. 3-30

**9.03 x 10⁻⁴ moles/l inorganic carbon;
1.27 x 10⁻³ moles/l SiO₂

TABLE 3C

EXPECTED GEOTECHNICAL PARAMETERS
FOR GEOLOGIC REPOSITORIES IN
TUFF

PARAMETER	VALUE	REFERENCE	COMMENT	PARAMETER	VALUE	REFERENCE	COMMENT
Depth	a) 884 m b) 300 m		2 Potential Horizons	Rock Fabric	Various Compositions and grain sizes. Generally fine grained.		
Design Basis Earthquake	TBD			Interstitial Gas	TBD		
In Situ Pressure				Mineral Constituents	a) See Table 3C-1, 3C-2 b) TBD		
Lithostatic	a) 16.5 MPa b) TBD			Water Constituents	a) See Table 3C-3 b) TBD		
Hydrostatic	a) 1.5-3.0 MPa b) 0.11 MPa	est.		Compressive Strength	a) 30-56 MPa b) TBD	3-26	RANGE 30-200 MPa
Maximum Design Pressure	a) 3.0 MPa b) 0.11 MPa	est.		Tensile Strength	a) 1-3 MPa b) TBD		
Fractures - Spacing	a & b) 0.5 - 3 m ₃		RANGE 2.1-2.4 g/cm ³	Young's Modulus	a) 8 GPa b) TBD		RANGE 6-26 GPa
Density	a) 2.18 g/cm ³ b) 2.12 g/cm ³			Poisson's Ratio	a) 0.25 b) TBD		RANGE 0.12-0.32
Porosity	a) 26% b) 17%		a) 100% saturated b) 80% saturated	Creep	TBD		
Permeability	a) 10 ⁻³ -10 ⁻¹ md b) TBD		Laboratory Determined Matrix Values	Thermal Conductivity	SATURATED DRY a) 1.85 W/mK 1.1 W/mK b) 1.8 W/mK 1.6 W/mK		
Hydraulic Conductivity	a) 1.2 x 10 ⁻⁴ m/s b) TBD			Thermal Expansion	a) 12x10 ⁻⁶ °C ⁻¹ b) 10.7 x 10 ⁻⁶ °C ⁻¹	3-27	
Sorptive Capacity - H ₂ O	a & b) 27%			Specific Heat, C _p	a) 1.75 kJ/kgK b) 1.03 kJ/kgK wet b) 0.83 kJ/kgK dry		
Sorptive Capacity-Nuclides	WELDED TUFF			Ambient Repository Temperature	a) 35°C b) TBD		
Sr	53-190 ml/g	3-25	3-25				
Cs	150-870 ml/g		3-25				
Ba	430-1500 ml/g		3-25				
Eu	90-7500 ml/g		3-25				
Pu	110 ml/g		3-25				
Am	130 ml/g		3-25				
Sorptive Capacity	a) 2.0-3.0 meq/100 g b) TBD						
Cation Exchange Capacity							

NOTE: a) Values for designs below the water table.
b) Values for designs above the water table

TABLE 3C-1
MINERALOGY OF REFERENCE WELDED TUFF

	<u>TYPICAL RANGE (VOLUME PERCENT)</u>	<u>REFERENCE VALUE (VOLUME PERCENT)</u>
Principal Mineral Phases		
Smectite and Mixed-Layer Clay	2-10	6
Mica and Illite Clay	2- 5	4
Quartz	15-40	28
Cristobalite	2-10	6
Alkali Feldspar	30-50	40
Phenocryst Phases (0.5-10 mm)	5-15	10
Quartz		
Plagioclase		
Sanidine		
Biotite		
Ilmenite		
Magnetite		
Lithics (1-10 mm)	2-10	6
Welded Tuff		
Sediments		

TABLE 3C-2
MAJOR ELEMENT BULK COMPOSITION
FOR REFERENCE WELDED TUFF

	TYPICAL RANGE (WT %)	REFERENCE COMPOSITION* (WT %)
SiO ₂	68-75	72.4
TiO ₂	0.0-0.4	0.1
Al ₂ O ₃	10-17	13.3
Fe ₂ O ₃	0.1-2.0	0.4
FeO	0.1-2.0	0.2
MnO	0.0-0.2	0.1
MgO	0.1-1.5	0.7
CaO	0.5-2.5	1.8
Na ₂ O	1.0-6.0	3.8
K ₂ O	2.0-7.0	4.2
P ₂ O ₅	0.0-0.2	0.1
S	0.0-2.0	0.1
H ₂ O*	1.0-5.0	<u>2.0</u>
		99.2

*Does not include pore water

TABLE 3C-3
REFERENCE GROUNDWATER COMPOSITION FOR
TUFF REPOSITORIES (BASED ON COMPOSITION
OF JACKASS FLATS WELL J-13 AT THE NEVADA TEST SITE)

	<u>CONCENTRATION (MG/LITER)</u>
Lithium	0.05
Sodium	51.
Potassium	4.9
Magnesium	2.1
Calcium	14.
Strontium	0.05
Barium	0.003
Iron	0.04
Aluminum	0.03
Silica	61.
Fluoride	2.2
Chloride	7.5
Carbonate	0.0
Bicarbonate	120.
Sulfate	22.
Nitrate	5.6
Phosphate	0.12

pH - slightly basic (7.1)

Eh - mildly oxidizing

The oxygen content of J-13 water has been reported to be as high as 7 ppm (oxygen saturation). However, some tests have taken place in which crushed tuff and J-13 water were shaken together for about one-year to yield redox potentials which are reducing. Additional experimentation is underway to further define redox conditions. Because of this uncertainty, Tuff groundwater should be considered to be saturated with oxygen at ambient temp. (35°C) and available in unlimited quantity.

TABLE 3D
EXPECTED GEOTECHNICAL PARAMETERS
FOR GEOLOGIC REPOSITORIES IN
GRANITE

<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>	<u>COMMENT</u>	<u>PARAMETER</u>	<u>VALUE</u>	<u>REFERENCE</u>
Depth	600 m	3-16		Rock Fabric	Medium grained with well-formed crystals	
Design Basis Earthquake	0.3 g	3-2		Interstitial Gas	TBD	
In Situ Pressure				Mineral Constituents	See Table 3D-1	
Lithostatic	16.2 MPa	Calc.	Calculated as per References 3-3 and 3-4	Water Constituents	TBD	
Hydrostatic	6.0 MPa	Calc.		Compressive Strength	200 MPa	3-5
Maximum Design Pressure	TBD			Tensile Strength	14 MPa	3-5
Fractures - Spacing	TBD			Young's Modulus	70 GPa	3-5
Density	2.6 g/cm ³	3-5		Poisson's Ratio	0.25	3-5
Porosity	0.5-2%	3-5		Creep	Neg.	
Permeability	10 ⁻² -1 md	3-16		Thermal Conductivity	4 W/mK	3-5
Sorptive Capacity - H ₂ O	0-0.32%	3-8		Thermal Expansion	7x10 ⁻⁶ °C ⁻¹	3-5
Sorptive Capacity-Nuclides				Specific Heat Capacity	1 kJ/kgK	3-5
Sr	5-15 ml/g	3-5				
Cs	400-700 ml/g	3-5				
Ba	100 ml/g	3-5				
Eu	300 ml/g	3-5				
Pu	5,000 ml/g	3-5				
Am	60,000 ml/g	3-5				
Sorptive Capacity - Cation Exchange Capacity	None Reported					

TABLE 3D-1
GRANITE MINERAL CONSTITUENTS

SiO_2	77.0%
Al_2O_3	12.0%
Fe_2O_3	0.8%
FeO	0.9%
CaO	0.8%
Na_2O	3.2%
K_2O	4.9%
H_2O	0.3%
X_yO	0.1%

Reference 3-8

TABLE 4
SHIPPING CASKS FOR CURRENT GENERATION LWR SPENT FUEL*

Cask Designation ^a	Number Casks Available	Number of Assemblies		Approximate Loaded Cask Weight		Usual Transport Mode	Shielding		Cavity Coolant	Cavity Dimensions (cm)	Maximum Heat Removal, kW
		PWR	BWR	MT	(Ton)		Gamma	Neutron			
NFS-4 or NAC-1	3 2	1	2	23	(25)	Truck	Lead 16.8 cm Steel 4 cm	Borated water and antifreeze 11.4 cm	Water	34DIA x 452LG	11.5
NLI 1/2	5	1	2	22	(24)	Truck	Lead 5.4 cm Uranium 7 cm Steel 3.8 cm	Water 12.7 cm	Helium	34DIA x 452LG	10.6
TN-8	2	3	-	36	(40)	Truck ^b	Lead 18.5 cm Steel 6 cm	Borated solid resin 15 cm	Air	3 PWR Cells	35.5
TN-9	3	-	7	35	(38)	Truck ^b	Lead 18.5 cm Steel 6 cm	Borated solid resin 15 cm	Air	7 BWR Cells	24.5
IF-300	3	7	18	63	(70)	Rail ^c	Uranium 10 cm Steel	Water and antifreeze 11.4 cm	Water	95DIA x 457LG	76 ^d
NLI 10/24	2	10	24	88	(97)	Rail	Lead 15 cm Steel 5-8.6cm	Water 22.8 cm	Helium	114DIA x 456LG	97 ^e
FSV ^h	3	9	9	22	(24)	Truck	TBD	TBD	TBD	42DIA x 476LG	
TN-12	-	12	32	97	(107) ^f	Rail	Steel	Borated solid resin	Air	TBD	135

*Reference DOE-ET-0054, 7/78 (All Data for Reference Only)

- a. Cask initials:
NAC = Nuclear Assurance Corp.
NFS = Nuclear Fuel Services, Inc.
NLI = NL Industries (previously National Lead Co.)
TN = Trans Nucleaire
IF = "Irradiated Fuel," symbol used by General Electric Corporation
- b. Overweight permit required. The TN-8 and TN-9 casks are also licensed for rail and water shipments.
- c. Truck shipment for short distances with overweight panels.
- d. Licensed decay heat load is 62 kW.
- e. Licensed decay heat load is 70 kW.
- f. With a cask body extension for abnormally long fuel, the loaded cask weight is 103 MT (113 tons).
- g. Designed for six HTGR fuel elements; 1800 lbs. total.
- h. Does not have adequate neutron shielding for spent LWR fuel. (FSV = Fort Saint Vrain).

TABLE 5
TRANSPORTATION IMPOSED LOADS
ON THE CANISTER ENCLOSED WASTE FORM
OR RETRIEVABLE PACKAGE

MAXIMUM IMPOSED LOADS	MAXIMUM ² TRANSPORT	NORMAL ¹ TRANSPORT
Flat Bottom Drop (g)	39.4	--
Side (g)	9.62 (drop)	5
Flat Top Drop (g)	39.4	--
Horizontal Accel. (g)	39.4	10

- (1) Normal transportation design basis (unless exceeded no requirement for any waste package concern, but would require evaluation if exceeded for repair/repackaging considerations).
- (2) Maximum waste package loads to be accommodated without breaching (would require repair/repackaging considerations).

Reference NRC Certificate of Compliance No. 9111 for Model No. NL1-1/2 Shipping Package Assessment.

TABLE 6

REASONABLE EXPECTED CONDITIONS UNDER WHICH COMBUSTION
MUST NOT BE INITIATED OR SUSTAINED BY THE WASTE PACKAGE

EVENT	CONDITION	REQUIREMENT/COMMENT
PYROPHORIC REACTION Spontaneous combustion of package/materials	Contact with oxidizer, sparking, or excess temperature experienced in accident or loss of control of cooling of package	No materials that are pyrophoric are permitted except as noted in (1)
COMBUSTION OF PACKAGE Materials, vehicle fuel tank rupture and fire	1/2 hour at maximum temperature of 800°C	Must not result in loss of integrity or release of waste from containers except as noted in (1)
ELECTRICAL ARCS AND FIRES	Electrical shorts resulting in the ignition of/or melt failure of cables/critical components in close proximity to package	Must not result in loss of integrity or release of waste from canisters except as noted in (1)
FIRES FROM LUBRICANT/ TRANSMISSION FLUID COMBUSTION	Combustion of spills, accumu- lations, gearbox fires, hydraulic fluid ignition. 1/2 hour at maximum temperature of 800°C	Must not result in loss of integrity or release of waste from container except as noted in (1)

(1) Any single event will not cause jeopardy of any other element/unit package or release of radionuclides, and damaged component can be repaired/replaced/repackaged.

TABLE 7
WASTE FORM CHARACTERISTICS - SPENT FUEL FORM NUMBER 1

WASTE TYPE	SPENT FUEL					COMMENTS
WASTE SOURCE	PWR			BWR		
WASTE FORM	FUEL RODS		REF	FUEL RODS		
DIMENSIONS DIAMETER LENGTH (m)	0.3 4.7			0.31 4.5		See Note 1 on p. 56-A. See Table 7-1 for dimensions of most populous assemblies.
THERMAL CONDUCTIVITY (W/mK)	5.5 UO ₂ 0.17 Bulk	7-1		5.5 UO ₂ 0.17 Bulk	7-1	See Note 2 on 56-A. See Note 3 on 56-A.
SPECIFIC HEAT (J/kgC)	264 UO ₂	7-1		264 UO ₂	7-1	See Note 2 on 56-A.
DENSITY (g/cm ³)	2.4	Calc.		2.0	Calc.	See Note 4 on 56-A.
THERMAL EXPANSION (1/°C)	Not Needed			Not Needed		
HEAT GENERATION (kW/m ³)	3.0	Calc.		2.5	Calc.	See Note 5 on 56-A.
MELTING TEMP (°C)	Not Needed			Not Needed		
MAXIMUM TEMP (°C)	Dur.Pkg. Des.Life 375	Aft.Pkg. Des.Life TBD	7-3	Dur.Pkg. Des.Life 375	Aft.Pkg. Des.Life TBD	7-3
TIME OUT OF REACTOR (Years)	10			10		Project Assumption
AVERAGE BURNUP (Mwd/MTHM)	33,000	7-2		27,000	7-2	
WEIGHT OF U (kg)	See Table 7-1			See Table 7-1		
WEIGHT OF ASSEMBLY (kg)	See Table 7-1			See Table 7-1		
LEACH RATE, g/cm ² -day	1 x 10 ⁻⁵	7-4		1 x 10 ⁻⁵	7-4	

FIGURE 7-1

WASTE FORM CHARACTERISTICS - SPENT FUEL FORM NUMBER 1 (INTACT SPENT FUEL)

REF 7-2 BWR FUEL ROD ASSEMBLY

PWR FUEL ROD ASSEMBLY

TABLE 7-1
CHARACTERISTICS OF TYPICAL LWR FUEL ASSEMBLIES

<u>PARAMETER</u>	<u>PWR</u>	<u>BWR</u>
Overall assembly length, m	4.1	4.5
Cross section, cm	21.4 x 21.4	13.9 x 13.9
Fuel element length, m	3.8	4.1
Active fuel height, m	3.7	3.8
Fuel element OD, cm	0.95	1.2
Fuel element array	17 x 17	7 x 7
Assembly total weight, kg	670	279
U/assembly, kg	460	190
UO ₂ /assembly, kg	525	215
Zircaloy/assembly, kg	130 ^a	57 ^b
Hardware/assembly, kg	16 ^c	8 ^d
Total metal/assembly, kg	145	65

-
- a. Includes Zircaloy control-rod guide thimbles.
 - b. Includes Zircaloy fuel-rod spacers.
 - c. Includes 10-kg SS nozzles and 5.5-kg Inconel*-718 grids.
 - d. Includes SS tie plates and negligible amount of Inconel* springs.

* Trademark of International Nickel Company

REF 7-2

TABLE 7-2
SPENT FUEL ASSEMBLY THERMAL LEVELS AND RADIOACTIVITY CONTENT

<u>YEARS OUT OF REACTOR</u>	<u>THERMAL OUTPUT (kW)</u>		<u>RADIOACTIVITY CONTENT (CURIES)</u>	
	<u>PWR</u>	<u>BWR</u>	<u>PWR</u>	<u>BWR</u>
1	4.8	TBD	2.5×10^6	TBD
10	0.55	TBD	4.0×10^5	TBD
50	0.25	TBD	1.0×10^5	TBD
100	0.13	TBD	5.0×10^4	TBD
500	0.045	TBD	2.5×10^3	TBD
1,000	0.026	TBD	1.7×10^3	TBD
10,000	0.006	TBD	4.5×10^2	TBD

REF 7-2

NOTE: The average fuel burnup (MWd/MT) for PWR and BWR are 33,000 and 27,500, respectively.

TABLE 8
WASTE FORM CHARACTERISTICS - SPENT FUEL FORM NUMBER 2

WASTE TYPE	SPENT FUEL						COMMENTS
WASTE SOURCE	PWR			BWR			
WASTE FORM	FUEL RODS			FUEL RODS			
			REF			REF	
DIMENSIONS DIAMETER (mm) LENGTH (m)	Max 11.18 4.1	Min 9.50 3.48		Max 14.48 4.1	Min 12.0 3.95		See Tables 8-1, 8-2 and 8-3 for additional detail.
THERMAL CONDUCTIVITY (W/mK)	5.5		8-2	5.5		8-2	
SPECIFIC HEAT (J/kgC)	264		8-2	264		8-2	See Note 1
DENSITY (g/cm ³)	2.0		CALC.	2.4		CALC.	See Note 2
THERMAL EXPANSION (1/°C)	---			---			Information not needed.
HEAT GENERATION (kW/m ³)	See Table 8-4.			See Table 8-4			
MELTING TEMP (°C)	---			---			Information not needed.
MAXIMUM TEMP (°C)	Dur.Pkg. Des.Life 375	Aft.Pkg. Des.Life TBD	8-4	Dur.Pkg. Des.Life 375	Aft.Pkg. Des.Life TBD	8-4	See Note 3
TIME OUT OF REACTOR (Years)	10			10			Project Assumption.
AVERAGE BURNUP (MWd/MTHM)	33,000		8-5	27,000		8-5	
WEIGHT OF U (kg)	Min 1.63	Max 2.15		Min 2.75	Max 2.97		Computed from Tables 8-1, 8-2 and 8-3.
WEIGHT OF ROD (kg)	2.5		CALC	4.4		CALC	
LEACH RATE ₂ g/cm ² -day	1 x 10 ⁻⁵		8-4	1 x 10 ⁻⁵		8-4	

TABLE 8-1
PHYSICAL CHARACTERISTICS OF TYPICAL BWR FUEL ASSEMBLIES

Reactor Type	BWR	BWR	BWR	BWR	BWR	BWR	BWR	BWR	BWR
Fuel Designer	GE	nr	GE	GE	GE	GE	GE	GE	GE
Fuel Rod Array	8x8	8x8	8x8	8x8	8x8	8x8	8x8	7x7	7x7
Designation	nr	nr	nr	nr	BWR 2/5R	BWR 2/5R	BWR/6	nr	nr
Specific Reactor	nr	nr	nr	nr	DAEC	NMP-1	Gr and Gulf	nr	nr
<u>Intact Fuel Assembly</u>									
Overall Length, m	4.470	4.5	4.354	4.470	4.474	4.35	nr	4.35	4.470
Maximum Envelope, cm	13.9x13.9	13.9x13.9	13.9	(13.9) ²	13.9x13.9	13.9x13.9	nr	13.37	(13.81) ²
Fuel Rod Pitch, cm	nr	nr	1.63	1.63	1.63	1.63	nr	1.87	1.87
Number of Fueled Rods	nr	nr	63	nr	62	62	62	49	nr
Integral Poison Rods	nr	nr	nr	nr	yes (f)	yes (f)	yes (f)	nr	nr
Weight-Fuel Bundle, kg	275.7	279	278	nr	272.7	265.9	nr	308	nr
Weight-UO ₂ Gd ₂ O ₃ , kg	nr	nr	nr	nr	207.4	200.8	nr	nr	nr
Weight-UO ₂ , kg	208.0	215	nr	nr	206.9	200.4	207.5	nr	nr
Weight-U, kg	183.3	190	nr	nr	182.4	176.7	nr	nr	nr
Weight-Zirconium Alloy, kg	57.9	57	nr	nr	nr	nr	nr	nr	nr
Weight-Other Alloys, kg	9.77	8	nr	nr	nr	nr	nr	nr	nr
Weight-Total Metals, kg	67.7	65	nr	nr	nr	nr	nr	nr	nr
Material-Fuel Clad	nr	Zirc 2+4	Zr-2	Zr-2	Zirc-2	Zirc-2	Zirc-2	Zirc-2	Zirc-2
<u>Fuel Rod Assembly</u>									
Overall Length, m	4.064	4.1	nr	nr	4.10	3.95	4.064	nr	nr
Active Fuel Length, m	3.759	3.8	3.71-3.76	3.658	3.81	3.69	3.81	3.66-3.71	3.66
Rod Diameter, mm	12.52	12	12.52	12.52	12.26	12.26	12.268	14.30	14.48
Clad Wall Thickness, mm	nr	nr	0.86	0.86	0.81	0.81	0.81	0.81-0.94	0.90
Pellet Diameter, mm	nr	nr	nr	10.57	10.41	10.41	10.41	nr	12.40
Radial Gap, mm	nr	nr	nr	0.11	0.12	0.12	nr	nr	0.14
Pellet Density, % theo.	nr	nr	nr	nr	95	95	nr	nr	nr

nr = not reported

N/A = not applicable

SS = stainless steel

Zirc - zirconium alloy not specified

TABLE 8-2
PHYSICAL CHARACTERISTICS OF PWR ASSEMBLIES

Reactor Type	PWR	NR	PWR	PWR	PWR	PWR	PWR	PWR	PWR
Fuel Designer	W	W	W	W	W	W	W	W	W
Fuel Rod Array	17x17	17x17	17x17	17x17	17x17	17x17	14x14	14x14	14x14
Designation	nr	nr	nr	nr	nr	nr	nr	nr	nr
Specific Reactor	nr	nr	nr	nr	Trojan	nr	nr	nr	nr
Source of Information	(a)	(b)	(e)	(c)	(d)	(c)	(e)	(c)	(c)
<u>Fuel Bundle Assembly</u>									
Overall Length, m	4.058	4.1	4.1	4.064	4.059	5.055	nr	4.064	3.48
Maximum Envelope, cm	21.4x21.4	(21.4) ²	(21.4) ²	(21.4) ²	(21.4) ²	(21.4) ²	19.7	(19.72) ²	(19.72) ²
Fuel Rod Pitch, cm	nr	nr	1.26	1.26	1.26	1.26	1.41	1.44	1.41
Number of Fueled Rods	nr	nr	264	nr	264	nr	179	nr	nr
Integral Poison Rods	nr	nr	none	nr	none	nr	nr	nr	nr
Weight-Fuel Bundle, kg	665	670	665	nr	nr	nr	nr	nr	nr
Weight-UO ₂ Gd ₂ O ₃ , kg	--	--	--	--	--	--	--	--	--
Weight-UO ₂ , kg	523	525	nr	nr	523.5	nr	nr	nr	nr
Weight-U, kg	461	460	nr	nr	461.5	nr	nr	nr	nr
Weight-Zirconium Alloy, kg	127	130	nr	nr	119.7	nr	nr	nr	nr
Weight-Other Alloys, kg	15	16	nr	nr	nr	nr	nr	nr	nr
Weight-Total Metals, kg	142	145	nr	nr	nr	nr	nr	nr	nr
Material-Fuel Clad	nr	SS	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	SS
Material-Poison Clad	nr	nr	nr	nr	304L	nr	nr	nr	nr
Material-Guide Tube	Zirc	Zirc	Zirc-4	nr	Zirc-4	nr	nr	nr	nr
Material-Water Rod	--	--	--	--	--	--	--	--	--
Material-Tie Plates	SS	SS	304SS	nr	304	nr	nr	nr	nr
Material-Spacers	Inconel	Inconel 718	Inconel 718	nr	Inconel	nr	nr	nr	nr
Material-Burnable Poison	nr	nr	nr	nr	Borosilicate	nr	nr	nr	nr
Material-Control Elements	nr	nr	nr	nr	Hg-In-Cd	nr	nr	nr	nr
<u>Fuel Rod Assembly</u>									
Overall Length, m	3.84	3.8	3.85-3.87	nr	3.851	nr	3.87	nr	nr
Active Fuel Length, m	3.658	3.7	3.658	3.658	3.658	4.166	3.658	3.658	3.048
Rod Diameter, mm	9.5	9.5	9.5	9.5	9.5	9.5	10.72	10.72	10.72
Clad Wall Thickness, mm	nr	nr	0.57	0.57	0.57	0.57	0.617	0.617	0.419
Pellet Diameter, mm	nr	nr	nr	8.19	8.19	8.19	nr	9.29	9.74
Radial Gap, mm	nr	nr	nr	0.084	0.084	0.084	nr	0.097	0.071
Pellet Density, % theo.	nr	nr	nr	nr	95	nr	nr	nr	nr

nr = not reported

N/A = not applicable

SS = stainless steel

Zirc = zirconium alloy not specified

TABLE 8-3
PHYSICAL CHARACTERISTICS OF PWR ASSEMBLIES

Reactor Type	PWR	PWR	PWR	PWR	PWR	PWR	PWR	PWR	PWR	PWR
Fuel Designer	CE	CE	CE	CE	CE	CE	B&W	B&W	B&W	B&W
Fuel Rod Array	16x16	16x16	16x16	14x14	14x14	14x14	17x17	17x17	15x15	15x15
Designation	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Specific Reactor	nr	nr	San Onofre 2	nr	nr	nr	nr	nr	nr	nr

Intact Fuel Assembly

Overall Length, m	4.49	4.496	4.486	3.716-3.994	4.166	3.994	4.216	4.208	4.216	4.206
Maximum Envelope, cm	20.68	(20.78) ²	20.90x20.90	20.68	(20.78) ²	20.90x20.90	(21.68) ²	21.68	(21.68) ²	21.68
Fuel Rod Pitch, cm	1.29	1.29	1.29	1.47	1.47	1.47	1.27	1.28	1.44	1.44
Number of Fueled Rods	236	nr	220-236	176	nr	168-176	nr	254	nr	208
Integral Poisoned Rods	nr	nr	yes (e)	nr	nr	yes (e)	nr	nr	nr	nr
Weight-Fuel Bundle, kg	650	nr	681	581	nr	545.7	nr	683	nr	689
Weight-UO ₂ Gd ₂ O ₃ , kg	--	--	--	--	--	--	--	--	--	--
Weight-UO ₂ , kg	nr	nr	451.0-483.8	nr	nr	411.6-431.2	nr	nr	nr	nr
Weight-U, kg	nr	nr	397.6-426.5	nr	nr	362.8-380.1	nr	nr	nr	nr
Weight-Zirconium Alloy, kg	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Weight-Other Alloys, kg	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Weight-Total Metals, kg	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Material-Fuel Clad	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4	Zirc-4

Fuel Rod Assembly

Overall Length, m	4.097	nr	4.099	3.48-3.73	nr	3.73	nr	nr	nr	nr
Active Fuel Length, m	3.810	3.810	3.810	3.25-3.48	3.48	3.47	3.63	3.63	3.66	3.66
Rod Diameter, mm	9.70	9.70	9.70	11.18	11.18	11.18	9.63	9.63	10.92	10.93
Clad Wall Thickness, mm	0.635	0.635	0.635	0.66&0.71	0.66	0.66	0.597	0.609	0.673	0.671
Pellet Diameter, mm	nr	8.26	8.26	nr	9.64	9.65	8.21	nr	9.40	nr
Radial Gap, mm	nr	0.089	0.089	nr	0.11	0.11	0.112	nr	0.089	nr
Pellet Density, % theo.	nr	nr	95	nr	nr	95	nr	nr	nr	nr

nr = not reported

N/A = not applicable

SS = stainless steel

Zirc = zirconium alloy not specified

TABLE 8-4

SPENT FUEL (FORM 2) HEAT GENERATION RATES

Time After Emplacement (Years)	Heat Generation Rate Per Fuel Rod (W)	
	PWR	BWR
0	2.08	3.02
5	1.75	--
10	1.56	--
15	1.42	--
20	1.30	--
30	1.09	--
40	0.94	1.35
50	0.81	--
70	0.63	--
90	0.63	--
100	0.50	0.75
190	0.29	--
290	0.23	--
390	0.19	--
450	0.17	--
990	0.097	0.14
1990	0.051	--

TABLE 9
WASTE FORM CHARACTERISTICS - COMMERCIAL HIGH-LEVEL⁽¹⁾ WASTE

WASTE TYPE	UNITS	HIGH LEVEL WASTE	
WASTE SOURCE		COMMERCIAL	
WASTE FORM		GLASS	SOURCE
Dimensions	-(m)	See Fig.	9-1
Thermal Conductivity	(W/m°C)	0.8-1.3 ⁽²⁾	9-1
Specific Heat	(J/kg-°C)	700-800 ⁽³⁾	9-1
Density	(g/cm ³)	3.1	9-1
Thermal Expansion	(1/°C)	1×10^{-5}	9-1
Heat Generation	kW	See Table 9-1	
Melting Temperature	°C	1050-1150	9-1
Maximum Temperature	During Design Life °C	500	9-1
	After Design Life °C	100	9-4,5
Composition		See Table 3-2	
Equivalent MIU of HLW per canister	MTU	2.28	9-1
Dose Rate at Surface of Canister	neutrons mrem/h	1.15×10^4	(4)
	gammas mrem/h	1.43×10^8	
Shear Strength	(Pa)	TBD	
Tensile Strength	(Pa)	4×10^7	9-1
Compressive ⁽⁵⁾ Strength	(Pa)	1.2×10^9	
Bulk ⁽⁵⁾ Modulus	(Pa)	3.8×10^{10}	
Shear ⁽⁵⁾ Modulus	(Pa)	2.9×10^{10}	
Youngs ⁽³⁾ Modulus	(Pa)	7×10^{10}	9-1
Leach Rate	g/cm ² - day (025°C)	$1.0-2.0 \times 10^{-6}$	9-1

(1)Reference Glass is very similar to HLW glass 77-260 developed for AGNS-FRP.

(2)Thermal Conductivity Range from 0 to 500°C

(3)Estimated

(4)Based on Radiation Source Terms in Ref. 9-1 plus an allowance for an additional neutron source term arising from (α, n) in neutrons in the Reference 77-260 glass

(5)Typical for Borosilicate Glass

TABLE 9-1
CHLW HEAT GENERATION RATE*

Time After Emplacement** (Years)	Heat Generation Rate (W)
0	2210
10	1600
40	798
90	292
990	20.1

*Reference 9-1.

**Waste is 10 Years Old at Emplacement.

TABLE 9-2
CHLW COMPOSITION*

<u>Constituent</u>	<u>Wt %</u>
SiO ₂	36
B ₂ O ₃	9
P ₂ O ₅	2
Alkali Metal Oxides	13
Alkaline Earth Oxides	1
Fe ₂ O ₃ , Cr ₂ O ₃ , NiO	1
Al ₂ O ₃	2
TiO ₂	6
ZnO	-
CuO	3
PbO	-
Gd ₂ O ₃	10
Fission Product Oxides	12
Actinide Oxides	5

*Reference 9-1.

TABLE 10
WASTE FORM CHARACTERISTICS - DEFENSE HIGH LEVEL WASTE FORM NUMBER 1

WASTE TYPE	UNITS	HIGH LEVEL WASTE	
WASTE SOURCE		COMMERCIAL	
WASTE FORM		GLASS	SOURCE
Dimensions	(m)	See Fig.	10-2
Thermal Conductivity	(W/m°C)	See Table 10-1	10-2
Specific Heat	(J/kg-°C)	See Table 10-2	10-2
Density	(g/cm ³)	See Table 10-3	10-2
Thermal Expansion	(1/°C)	1.22×10^{-5}	10-2
Heat Generation	kW	See Table 10-4	10-2
Melting Temperature	°C	930	10-1
Maximum Temperature	During Containment Design Life °C	500 ⁽¹⁾	10-2
	After Containment Design Life °C	100	10-1
Dose Rate at Surface of Canister	neutrons mrem/hr	7.3×10^1	(4)
	gamma mrem/hr	2.56×10^7	
Glass Composition	See Table 10-S		10-2
Shear Strength	(Pa)	TBD	10-2
Tensile Strength	(Pa)	6.2×10^7	10-2
Compressive Strength	(Pa)	6.9×10^8	10-2
Bulk Modulus	(Pa)	3.8×10^{10}	(3)
Shear Modulus	(Pa)	2.9×10^{10}	(3)
Youngs Modulus	(Pa)	6.2×10^{10}	10-2
Leach Rate	g/cm ² - day	1×10^{-7}	10-2
Labeling	See Below

NOTE: Labeling - Each canister will have a number stamped on the horizontal and vertical faces of the upper flange. The numbers will be approximately 2.54 cm (1 in.) high and will be visible by television viewing. Each number will identify the canister fabrication and processing history.

(1) Unless noted otherwise, values are for Stage 1 composite, TDS-3A waste glass

(2) Experimentally determined for FRIT 131.

(3) Typical for Borosilicate glass.

(4) Gamma dose rate based on Ref. 10-2. Neutron dose rate is a rough estimate of the dose rate created by (α , η) neutrons generated in the Borosilicate glass.

TABLE 10-1
DHLW (FORM 1) THERMAL CONDUCTIVITY

<u>Temperature (°C)</u>	<u>Thermal Conductivity (W/mK)</u>
0	0.847
100	0.972
200	1.097
300	1.222
400	1.347
500	1.472
600	1.598

Reference 10-2

TABLE 10-2
DHLW (FORM 1) HEAT CAPACITY

<u>Temperature (°C)</u>	<u>Heat Capacity (J/kgC)</u>
0	778.
100	992.
200	1135.
300	1238.
400	1315.
500	1373.
600	1415.

Reference 10-2

TABLE 10-3
DHLW (FORM 1) DENSITY

<u>Temperature (°C)</u>	<u>Density (g/cm³)</u>
20	2.750
100	2.743
200	2.735
300	2.726
450	2.718
500	2.713
600	2.672

Reference 10-2

TABLE 10-4
DHLW (FORM 1) HEAT GENERATION RATE*

Time After Emplacement** (Years)	Heat Generation Rate (W)
0	423
5	292
10	256
15	228
20	203
25	181
30	162
35	145
45	117
70	69
95	42
195	8.7
255	3.5
395	2.0
495	1.3
745	0.75
995	0.57

* Stage 2 glass.

** Waste is 5 years old at emplacement.

Reference 10-2

TABLE 10-5
DHLW GLASS COMPOSITION

<u>Oxide</u>	<u>Weight Percent</u>	
	<u>Stage 1</u>	<u>Stage 1/Stage 2</u>
Li ₂ O	4.23	4.25
B ₂ O ₃	10.9	10.9
TiO ₂	0.743	0.746
CaO	1.16	1.04
Na ₂ O	15.0	16.3
SiO ₂	45.5	46.3
Fe ₂ O ₃	6.57	5.90
Al ₂ O ₃	3.62	3.25
MnO	1.81	1.62
UO ₂	1.30	1.17
NiO	0.677	0.607
MgO	1.64	1.63
ZrO ₂	0.371	0.373
La ₂ O ₃	0.371	0.373
Zeolite	1.59	1.43
Fe ₃ O ₄	3.13	2.81
Other	1.388	1.301

Reference 10-2

TABLE 11

WASTE FORM CHARACTERISTICS - DEFENSE HIGH LEVEL WASTE FORM NUMBER 2

WASTE TYPE	UNITS	HIGH LEVEL WASTE	
WASTE SOURCE		DEFENSE	
WASTE FORM			SOURCE
Dimensions	(m)	See Fig.	11-1
Thermal Conductivity	(W/m°C) 20°C	1.7	11-1
Specific Heat	(J/kg-°C)	N.S.	11-1
Density	(g/cm ³)	4.0	11-1
Thermal Expansion	(1/°C)	1.0×10^{-5} (20-425°C)	11-1
Heat Generation	(kW/m ³)	See Table 11-1	11-1
Melting Temperature	(°C)	1270	11-1
Maximum Temperature	During Containment Design Life °C	TBD	11-1
Radiation Source Term	See Tables 11-2, 3		11-1
Glass Composition	See Tables 11-4, 5		11-1
Flexural Strength	(Pa)	6.4×10^7	11-1
Tensile Strength	(Pa)	N.S.	11-1
Compressive Strength	(Pa)	3.5×10^8	11-1
Bulk Modulus	(Pa)	1.1×10^{11}	11-1
Shear Modulus	(Pa)	5.4×10^{10}	11-1
Youngs Modulus	(Pa)	1.6×10^{11}	11-1
Leach Rate	g/cm ² - day	See Table 11-6	11-1

N.S. = None Specified

TABLE 11-1

CANISTER HEAT GENERATION

<u>YEARS</u>	<u>WATTS</u>	
	<u>STAGE 1</u>	<u>STAGE 1/STAGE 2 *</u>
5	1448	1472
10	894	1016
15	780	891
20	693	793
25	616	706
30	553	630
35	494	564
40	445	505
50	358	407
75	216	240
100	136	146
200	35	30
300	16	12
400	9.1	7.0
500	6.3	4.5
750	3.4	2.6
1000	2.6	2.0

*Reference Design Parameters

TABLE 11-2

RADIATION FROM CANISTER OF STAGE 1/STAGE 2 CERAMIC WASTE*

<u>DISTANCE FROM SURFACE, cm</u>	<u>REM/HR</u>
1	8.63 E 04
10	6.33 E 04
30	3.69 E 04
90	1.15 E 04
180	4.11 E 03
200	3.47 E 03
210	3.16 E 03
500	6.44 E 02
1000	1.67 E 02
5000	6.86 E 00

*5-YR-OLD SLUDGE PLUS 15-YR-OLD SUPERNATE.

TABLE 11-3

Isotopic Content of Stage 1/2 Ceramic Waste Form

ISOTOPE	CI/LB	ISOTOPE	CI/LB	ISOTOPE	CI/LB
Cr 51	5.22E-20	Te127M	5.19E-05	Ti208	6.21E-07
Co 60	1.01E-01	Te129	1.29E-15	Ti209	2.54E-15
Se 79	8.02E-05	Te129M	2.02E-15	U 232	8.02E-06
Rb 87	5.32E-09	Cs134	7.93E-02	U 233	8.58E-10
Sr 89	2.99E-03	Cs135	8.91E-05	U 234	9.45E-06
Sr 90	1.80E+01	Cs137	1.66E+01	U 235	3.11E-08
Y 90	1.80E+01	Ba137M	1.57E+01	U 236	6.75E-07
Y 91	5.52E-07	La140	2.54E-40	U 238	1.71E-07
Zr 93	1.07E-03	Ce141	2.11E-14	Np236	1.02E-11
Zr 95	5.83E-06	Ce142	5.62E-09	Np237	5.19E-06
Nb 95	1.26E-05	Ce144	5.80E+00	Pu236	3.68E-05
Nb 95M	7.41E-03	Pr143	7.04E-38	Pu237	2.69E-15
Te 99	1.45E-03	Pr144	5.80E+00	Pu238	4.43E-01
Ru103	6.71E-12	Pr144M	6.96E-02	Pu239	4.17E-03
Ru106	8.76E-01	Nd144	2.83E-13	Pu240	2.64E-03
Rh103M	6.71E-12	Pm147	1.42E+01	Pu241	4.95E-01
Rh106	8.76E-01	Pm148	4.09E-14	Pu242	8.51E-06
Pd107	5.39E-06	Pm148M	5.92E-13	Am241	6.39E-03
Ag110	7.45E-03	Sm147	1.18E-09	Am242	8.41E-06
Cd115M	5.39E-13	Sm148	8.81E-15	Am242M	8.45E-06
Sn121M	1.93E-05	Sm149	1.03E-15	Am243	8.40E-06
Sn123	1.56E-04	Sm151	1.89E-01	Cm242	2.06E-05
Sn126	8.89E-06	Eu152	2.24E-03	Cm243	3.27E-06
Sb124	4.21E-11	Eu154	8.67E-01	Cm244	9.59E-05
Sb125	4.97E-01	Eu155	2.91E-01	Cm245	3.92E-09
Sb126	1.25E-06	Eu156	8.10E-35	Cm246	8.13E-10
Sb126M	8.89E-06	Tb160	6.55E-10	Cm247	3.84E-16
Te125M	1.17E-01	Ti206	2.83E-21	Cm248	4.01E-16
Te127	5.09E-05	Ti207	8.98E-11		
Total Activity			9.84E+01	CI/LB	
Decay Heat					
Total Primary			2.13E-01	WATT/LB	
Total Gamma			6.49E-02	WATT/LB	

TABLE 11-4

SRP CERAMIC WASTE FORMPHASE COMPOSITION

(SYNROC-D)

<u>MINERAL PHASE</u>	<u>APPROX. PHASE COMPOSITION</u>	<u>NORMAL FORM</u>	<u>WASTE ELEMENTS</u>
SPINEL	55%	$(\text{Fe}, \text{Mn}, \text{Ni})(\text{Al}, \text{Fe})_2\text{O}_4$	AL, FE, MN
PEROVSKITE	11%	CaTiO_3	SR, CE, EU
ZIRCONOLITE	16%	$\text{CaZrTi}_2\text{O}_7$	SR, U
NEPHELINE	18%	$\text{NaAlSi}_3\text{O}_8$	NA, CS, AL...

TABLE 11-5

FEED COMPOSITION FOR SRP CERAMIC WASTE FORM
OXIDE BASIS

<u>WT. % OXIDE OR SALT</u>	<u>SRL COMPOSITE (UNWASHED)</u>	<u>SYNROC ADDITIVES</u>
Fe ₂ O ₃	23.8	-
Al ₂ O ₃	18.6	-
MnO ₂	7.4	-
U ₃ O ₈	2.1	-
CaO	1.8	5.3
NiO	3.0	-
SiO ₂	0.6	6.6
Na ₂ O	3.3	-
Na ₂ SO ₄	0.6	-
MINORS (Cs, Ce, ...)	1.50	-
TiO ₂	-	18.8
ZrO ₂	<u>-</u>	<u>6.6</u>
TOTAL	62.7	37.3

TABLE 11-6

LEACH RATES FOR SYNROC D
VIA MCC-1 AND MCC-2 28 DAY LEACH TESTS²

CONDITIONS/ELEMENT		LEACH RATE (g/m ² .d)
Deionized H ₂ O		
90°C	Cs	0.79
	Sr	0.38
	U	1.1 x 10 ⁻⁴
Silicate H ₂ O		
40°C	Cs	0.18
	Sr	0.033
	U	<0.0185
90°C	Cs	0.54
	Sr	0.099
	U	3.4 x 10 ⁻⁴
150°C	Cs	0.74
	Sr	0.493
Brine Solution		
40°C	Cs	<0.1
	Sr	<0.004
	U	<0.0185
90°C	Cs	<0.1*
	Sr	<0.71
	U	0.0005*
*MCC Data		

Reference 11-1

TABLE 12
WASTE FORM CHARACTERISTICS - DEFENSE HIGH
LEVEL WASTE FORM NUMBER 3

WASTE TYPE	UNITS	HIGH LEVEL WASTE	
WASTE SOURCE			
WASTE FORM			SOURCE
Dimensions	(m)		
Thermal Conductivity	(W/m ⁰ C)		
Specific Heat	(J/kg- ⁰ C)		
Density	(g/cm ³)		
Thermal Expansion	(1/ ⁰ C)		
Heat Generation	(kW/m ³)		
Melting Temperature	(⁰ C)		
Limiting Trans Temp. EMP	(⁰ C) (⁰ C)	-----	-----
Shear Strength	(Pa)		
Tensile Strength	(Pa)		
Compressive Strength	(Pa)		
Bulk Modulus	(Pa)		
Shear Modulus	(Pa)		
Youngs Modulus	(Pa)		
Leach Rate	g/cm ² -day		

These are the kinds of data needed to characterize this waste form.

TABLE 13

WASTE FORM CHARACTERISTICS - TRANSURANIC
WASTE FORM NUMBER 1

WASTE TYPE	UNITS	TRANSURANIC	
WASTE SOURCE			
WASTE FORM			SOURCE
Dimensions	(m)		
Thermal Conductivity	(W/m ⁰ C)		
Specific Heat	(J/kg- ⁰ C)		
Density	(g/cm ³)		
Thermal Expansion	(1/ ⁰ C)		
Heat Generation	(kW/m ³)		
Melting Temperature	(⁰ C)		
Limiting Temp. $\frac{\text{Trans}}{\text{EMP}}$	$\frac{(^{0}\text{C})}{(^{0}\text{C})}$	-----	-----
Shear Strength	(Pa)		
Tensile Strength	(Pa)		
Compressive Strength	(Pa)		
Bulk Modulus	(Pa)		
Shear Modulus	(Pa)		
Youngs Modulus	(Pa)		
Leach Rate	g/cm ² -day		

These are the kinds of data needed to characterize this waste form.

TABLE 14
WASTE FORM CHARACTERISTICS - TRANSURANIC
WASTE FORM NUMBER 2

WASTE TYPE	UNITS	TRANSURANIC	
WASTE SOURCE			
WASTE FORM			SOURCE
Dimensions	(m)		
Thermal Conductivity	(W/m ⁰ C)		
Specific Heat	(J/kg- ⁰ C)		
Density	(g/cm ³)		
Thermal Expansion	(1/ ⁰ C)		
Heat Generation	(kW/m ³)		
Melting Temperature	(⁰ C)		
Limiting Trans Temp. EMP	(⁰ C) (⁰ C)	-----	-----
Shear Strength	(Pa)		
Tensile Strength	(Pa)		
Compressive Strength	(Pa)		
Bulk Modulus	(Pa)		
Shear Modulus	(Pa)		
Youngs Modulus	(Pa)		
Leach Rate	g/cm ² -day		

These are the kinds of data needed to characterize this waste form.

TABLE 15
WASTE FORM CHARACTERISTICS - TRANSURANIC
WASTE FORM NUMBER 3

WASTE TYPE	UNITS	TRANSURANIC	
WASTE SOURCE			
WASTE FORM			SOURCE
Dimensions	(m)		
Thermal Conductivity	(W/m°C)		
Specific Heat	(J/kg-°C)		
Density	(g/cm ³)		
Thermal Expansion	(1/°C)		
Heat Generation	(kW/m ³)		
Melting Temperature	(°C)		
Limiting Temp. Trans EMP	(°C) (°C)	-----	-----
Shear Strength	(Pa)		
Tensile Strength	(Pa)		
Compressive Strength	(Pa)		
Bulk Modulus	(Pa)		
Shear Modulus	(Pa)		
Youngs Modulus	(Pa)		
Leach Rate	g/cm ² -day		

These are the kinds of data needed to characterize this waste form.

TABLE 16A
REFERENCE REPOSITORY THERMAL
CHARACTERISTICS - SALT

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Maximum Temp. °C	250 (16-1)	250 (16-1)	250 (16-1)
Local Thermal Loading			
kW/Acre	75 (16-2)	150 (16-2)	150 (16-2)
W/m ²	18.7 (16-2)	37.5 (16-2)	37.5 (16-2)

TABLE 16B
REFERENCE REPOSITORY THERMAL
CHARACTERISTICS - BASALT

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Maximum Temp. °C	450 (16-3)	450 (16-3)	450 (16-3)
Local Thermal Loading			
kW/Acre	190 (16-2)	190 (16-2)	190 (16-2)
W/m ²	47.5 (16-2)	47.5 (16-2)	47.5 (16-2)

TABLE 16C
REFERENCE REPOSITORY THERMAL
CHARACTERISTICS - TUFF

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Maximum Temp. °C	None	None	None
Local Thermal Loading			
kW/Acre	100	100	100
W/m ²	25	25	25

TABLE 16D
REFERENCE REPOSITORY THERMAL
CHARACTERISTICS - GRANITE

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Maximum Temp. °C	350	350	350
Local Thermal Loading			
kW/Acre	190	190	190
W/m ²	47.5	47.5	47.5

All Data from REF 16-2.

TABLE 17A
REFERENCE REPOSITORY EXCAVATION GEOMETRY
CONSTRAINTS ON RETRIEVABLE PACKAGE DESIGN
SALT

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Typical Disposal Room Height (m)	7.2	6.1	6.1
Typical Disposal Room Width (m)	7.0	5.5	6.1
Typical Adjacent Pillar Thickness (m)	21.3 (17-5)	18.3 (17-5)	18.0 (17-5)
Minimum Borehole Spacing* (m)	1.5 (17-2)	1.5 (17-2)	1.5
Expected Water Conditions (Liters)	<10	<20	< 5

*Edge to Edge Distance (Web Thickness)

TABLE 17B
REFERENCE REPOSITORY EXCAVATION GEOMETRY CONSTRAINTS
ON RETRIEVABLE PACKAGE DESIGN
BASALT

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Typical Disposal Room Height (m)	N.S.	N.S.	N.S.
Typical Disposal Room Width (m)	N.S.	N.S.	N.S.
Typical Adjacent Pillar Thickness (m)	N.S.	N.S.	N.S.
Minimum Borehole Spacing* (m)	1 x D	1 x D	1 x D
Expected Water Conditions	1 liter per year per square meter of exposed rock surface		

N.S. - Not Specified

*1 Emplacement Hole Diameter

TABLE 17C
REFERENCE REPOSITORY EXCAVATION GEOMETRY CONSTRAINTS
ON RETRIEVABLE PACKAGE DESIGN
TUFF

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Typical Disposal Room Height (m)	7.0	5.0	TBD
Typical Disposal Room Width (m)	7.5	5.0	TBD
Typical Adjacent Pillar Thickness (m)	30 (17-5)	20 (17-5)	TBD
Minimum Borehole Spacing* (m)	1.5 (17-2)	1.5 (17-2)	1.5 (17-2)
Expected Water Conditions	Unlimited Water Available		

* Edge to Edge Distance.

TABLE 17D
REFERENCE REPOSITORY EXCAVATION GEOMETRY CONSTRAINTS
ON RETRIEVABLE PACKAGE DESIGN
GRANITE

	<u>SPENT FUEL</u>	<u>CHLW</u>	<u>DHLW</u>
Typical Disposal Room Height (m)	7.0 (17-5)	7.0 (17-5)	7.0 (17-5)
Typical Disposal Room Width (m)	7.5 (17-5)	7.5 (17-5)	7.5 (17-5)
Typical Adjacent Pillar Thickness (m)	22.5 (17-5)	22.5 (17-5)	22.5 (17-5)
Minimum Borehole Spacing* (m)	1.5 (17-2)	1.5 (17-2)	1.5 (17-2)
Expected Water Conditions	Unlimited Water		

* Edge to Edge Distance.

TABLE 18
ACCEPTABLE CODES AND STANDARDS

The Engineered waste package design effort shall utilize accepted existing codes and standards. This will result in a design which can be produced and verified by proven existing technology and manufacturing techniques.

In general, the industry standards of the following organizations shall be acceptable for the engineered waste package design effort.

INDUSTRY STANDARDS

ACI	American Concrete Institute
AICHE	American Institute of Chemical Engineers
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society for Mechanical Engineers
ASQC	American Society for Quality Control
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CGA	Compressed Gas Association Inc.
IEEE	Institute of Electrical and Electronic Engineers
ISA	Instrument Society of America
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
SAE	Society of Automotive Engineers
UL	Underwriters Laboratories

TABLE 18 (CONT'D)

Some examples of codes and standards that could be applied are indicated below. This list is not meant to be all inclusive but to provide examples of types of codes and standards.

DESIGN

1. ASME, Boiler and Pressure Vessel Code, Section III Nuclear Power Plant Components (components important to safety).
2. ASME, Boiler and Pressure Vessel Code, Section VIII Pressure Vessels (other pressure containing components).
3. ANSI B31.1, Power Piping (appropriate components important to safety).
4. ANSI N45.2, Quality Assurance Program Requirements
5. ANSI N45.2.11, Quality Assurance Requirements for the Design of Nuclear Power Plants

STEEL

1. ASTM A-21, General Requirements for Steel Plates for Pressure Vessels.
2. ASTM A-36, Specification for Structural Steel.
3. ASTM A-116, Seamless Carbon Steel Pipe for High Temperature Service.
4. ASTM A-176, Stainless and Heat Resisting Chromium Steel Plate, Sheet and Strip.
5. ASTM A-269, Seamless and Welded Austenitic Stainless Steel Tubing for General Service.

TITANIUM

ASTM B-265, Titanium and Titanium Alloy Strip, Sheet and Plate.

ASTM B-337, Seamless and Welded Titanium and Titanium Alloy Pipe.

ALUMINUM

ASTM B-345, Aluminum Alloy Seamless Extruded Tube and Seamless Pipe.

TABLE 18 (CONT'D)

ZIRCONIUM

ASTM B-352, Zirconium and Zirconium Alloy Sheet, Strip, and Plate for Nuclear Applications.

ASTM B-353, Wrought Zirconium and Zirconium Alloy Seamless and Welded Tubes for Nuclear Service.

MOLYBDENUM

ASTM B-385, Molybdenum and Molybdenum Alloy Strip, Sheet, Foil and Plate.

WELDING

AWS - B1.1, Guide for Non-destructive Inspection of Welds.

AWS - B3.1, Welding Procedure and Performance Qualification.

AWS - D11.4, Recommended Practices for Welding Austenitic Chromium - Nickel and Stainless Steel Piping and Tubing.

COMPRESSED GAS

CGA - P-1-74, Safe Handling of Compressed Gases in Containers.

INSTRUMENTS

ISA - RP25.1-57, Tentative Recommended Practice, Materials for Instruments in Radiation Service.

FIRE PROTECTION

NFPA, Fire Protection Handbook

CONCRETE

ACI, Manual of Concrete Practice

TABLE 19
INTERIM STORAGE ENVIRONMENTAL CONDITIONS

The retrievable package (waste package components intended to be emplaced and retrieved as a unit) will be subject to environmental conditions during interim storage prior to emplacement and after retrieval. This could involve storage in the hot cell at the geologic repository overnight, over weekends, or longer due to shutdowns, or could involve longer storage at a separate storage facility prior to emplacement and after retrieval unit final disposition of the retrieved waste is achieved. Short term storage similar to the geologic repository hot cell could also exist at various waste facilities throughout the waste management system.

The following environmental conditions shall apply during these storage periods for the Engineered Waste Package:

1. Temperature

Maximum point temperature	Same as for geologic disposal.
Maximum Surface temperature	As limited by handling equipment.

2. Mechanical Loadings

Normal storage configuration Installation and removal loadings	Dead weight loads. 3 x dead weight loads for handling attachments.
Seismic loadings Accidental Drop	0.3g per design basis earthquake. Based on maximum possible drop distance.

4.2 TABLES REFERENCES AND NOTES

This section includes various references and notes for Paragraph 4.1.

REFERENCES FOR TABLES 3A to 3D

- 3-1 Not used.
- 3-2 Algermissen, S. T., and D. M. Perkins, "A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," USGS Open File Report 76-416, 1976.
- 3-3 Hoek, E., "The Role of Modeling in the Design of Nuclear Waste Repositories - The Designers Viewpoint: Proc. of a Workshop on Thermomechanical Modeling for a Hard Rock Waste Repository," UCAR-10043, Univ. of California, Berkeley, pp. 33-43., 1979.
- 3-4 Levorsen, A. I., Geology of Petroleum, W. H. Freeman and Co., San Francisco, p. 390, 1954.
- 3-5 Tyler, L. D., "Evaluation of Tuff as a Waste Isolation Medium," Sandia Corp., SAND 79-0402C, 1979.
- 3-6 Powers, D. W., S. J. Lambert, S. E. Shaffer, L. R. Hill, W. D. Weart, Editors, "Geological Characterization Report Waste Isolation Pilot Plant (WIPP) Site, Southeastern, New Mexico, SAND 78-1596, Vol. II, pp. 7-32 to 7-35, pp. 9-5 to 9-6, 1978.
- 3-7 Lester, D. H., "Performance Characteristics and Costs of Selected Engineered Barrier Concepts," ONWI-62, pp. 191-194, 1979.
- 3-8 Department of Energy, "Environmental Impact Statement," DOE/EIS-0046-F, Volume II, October 1980.
- 3-9 Rockwell Hanford Operations, "BWIP Data Package for Geotechnical Parameters for a Repository in Hanford Basalt," RSD-BWI-DP-028, 1981.
- 3-10 Not used.
- 3-11 Rockwell Hanford Operations, "BWIP Data Package for Model Generated Travel Times and Waste Package Performance Criteria," RSD-DWI-DP-013, 1981.
- 3-12 Not used.
- 3-13 Not used.

REFERENCES FOR TABLES 3A to 3D (Continued)

- 3-14 Not used.
- 3-15 Not used.
- 3-16 DOE, "Technology for Commercial Waste Management, Vol. 4, DOE/ET-0028, May 1979.
- 3-17 D'Appolonia, "Basic Salt Working Catalog," Report No. 79-339, 1980.
- 3-18 Not used.
- 3-19 Not used.
- 3-20 Claiborne, H. C., Rickertsen, L. D., and Graham, R. F., "Expected Environments in High-Level Nuclear Waste and Spent Fuel Repositories in Salt," ORNL/TM-7201, August 1980.
- 3-21 Not used.
- 3-22 Not used.
- 3-23 Not used.
- 3-24 Not used.
- 3-25 Johnstone, J. K., and Wolfsberg, K., eds., "Evaluation of Tuff as a Medium for a Nuclear Waste Repository: Interim Status Report on the Properties of Tuff," SAND80-1464, Sandia National Laboratories, Albuquerque, NM, 1980.
- 3-26 Olsson, W. A., and Jones, A. K., "Rock Mechanics Properties of Volcanic Tuffs From the Nevada Test Site," SAND80-1453, Sandia National Laboratories, Albuquerque, NM, 1980.
- 3-27 Lappin, A. R., "Preliminary Thermal Expansion Screening Data for Tuffs," SAND78-1147, Sandia National Laboratories, Albuquerque, NM, 1978.

REFERENCES FOR TABLES 3A to 3D (Continued)

- 3-28 Not used.
- 3-29 Not used.
- 3-30 Anderson, W. J., "Conceptual Design Requirements for Spent Fuel, High-Level Wastes and Transuranic Wastes Packages," RSD-BWI-FD-006-REV. 2 (Changed to SD-BWI-CR-005), Rockwell International, RHO, Feb. 1982.
- 3-31 Not used.
- 3-32 Not used.
- 3-33 Not used.

REFERENCES FOR TABLE 7

- 7-1 Y. S. Touloukian, et al. - Thermophysical Properties of High Temperature Solid Materials, McMillan, New York, 1967.
- 7-2 U. S. Department of Energy, "Confidence Rulemaking Statement of Position of the U. S. Department of Energy," DOE/NE-0007, April, 1980.
- 7-3 L. D. Blackburn and D. A. Cantley - Criteria for Maximum Allowable Fuel and Cladding Temperatures for Dry Storage of Spent Fuel, HEDL TC-1181, July 1978.
- 7-4 J. M. Rusin, W. J. Gray, J. W. Walt - Multibarrier Waste Forms Part II: Characterization and Evaluation, August 1979, Pacific Northwest Laboratories, PNL-2668-2.

NOTES FOR TABLE 7

- 1) The dimensions given were derived from a review of the various BWR and PWR spent assemblies and represent the maximum envelope for two side-by-side configured BWR's and or a single PWR with nozzle or attaching hardware removed in some cases.
- 2) Typical of unirradiated UO_2 .
- 3) Assumes helium backfill, neglecting convection and radiation.
- 4) Fuel bundle weight volume of container.

REFERENCES FOR TABLE 8

- 8-1 Not used.
- 8-2 Y. S. Touloukian, et al, Thermophysical Properties of High Temperature Solid Materials, McMillan, New York, 1967.
- 8-3 Not used.
- 8-4 L. D. Blackburn and D. A. Cantley, Criteria for Maximum Allowable Fuel and Cladding Temperatures for Dry Storage of Spent Fuel, HEDL TC-1181, July 1978.
- 8-5 U. S. Department of Energy, "Confidence Rulemaking - Statement of The U. S. Department of Energy," DOE/NE-007, April, 1980.

NOTES FOR TABLE 8

- 1) Typical of unirradiated UO_2 .
- 2) Fuel bundle weight volume of container.
- 3) Same transportation and storage limit based on preventing stress-rupture is assumed the same for PWR and BWR. The lower operating temperature for UO_2 is expected to be higher than value for glass.

REFERENCES FOR TABLE 9

- 9-1 Slate, S. C. et al, "Reference Commercial High-Level Waste Glass and Canister Definition," PNL-3838, September, 1981.
- 9-2 Not used.
- 9-3 Not used.
- 9-4 G. J. McCarthy et al. - Hydrothermal Reactivity of Simulated Nuclear Waste Forms and Water - Catalysed Waste - Rock Interactions, Scientific Basis for Nuclear Waste Management, Volume I, Plenum Press, NY 1979.
- 9-5 J. H. Westik, Jr. and R. P. Turcott - Hydrothermal Glass Reactions in Salt Brine, Scientific Basis for Nuclear Waste Management, Volume I, Plenum Press, NY, 1979.

REFERENCES FOR TABLE 10

- 10-1 Savannah River Laboratory, "Preliminary Technical Data Summary for the Defense Waste Processing Facility - Stage 1," DPSTD-80-30, E. I. du Pont de Nemours & Co., Sept, 1980.
- 10-2 Baxter, R. G., "Description of DWPF Reference Waste Form and Canister," DP-1606, E. I. du Pont de Nemours & Co., June 1981.

REFERENCES FOR TABLE 11

- 11-1 J. L. Butler, J. S. Allender and T. H. Gould, "Description of Ceramic Waste Form and Canister for Savannah River Plant Waste," DP-1626, E. I. du Pont de Nemours & Co., Aiken, SC, April 1982.

REFERENCES FOR TABLES 16A to 16D

- 16-1 Office of Nuclear Waste Isolation, "Interim Reference Repository Conditions for Commercial and Defense High-Level Nuclear Waste and Spent Fuel Repositories in Salt," NWTs-3, December 1980.
- 16-2 U. S. Department of Energy, "Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste, Volume 2 Appendices," DOE/EIS-0046F, October 1980, Section K.1.1.
- 16-3 Anderson, W. J., "Conceptual Design Requirements for Spent Fuel, High-Level Wastes and Transuranic Wastes Packages," RSO-BWI-FD-006-Rev. 2 (Changed to SD-BWI-CR-005) Rockwell International, RHO, Feb. 1982.

REFERENCES FOR TABLES 17A to 17D

- 17-1 Not used.
- 17-2 U. S. Department of Energy, "Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste, Volume 2 Appendices," DOE/EIS-0046F, October 1980, Section K.1.1.
- 17-3 Not used.
- 17-4 Not used.
- 17-5 Raines, G. E., "Development of Reference Repository Conditions," ONWI-212, December 1980.

DISTRIBUTION LIST

ACRES AMERICAN INC R STRUBLE	BUNDESMINISTERIUM FÜR FORSCHUNG ROLF-PETER RANDL	DRAGO ENGINEERS AND CONSTRUCTORS KEN BEALL
ALLIED GENERAL NUCLEAR SERVICES K J ANDERSON P F HIGHBERGER M A KOLB	BURNS AND ROE INDUSTRIAL SERVICES CORP JOHN PIRRO	DUKE UNIVERSITY THOMAS DAVIS
ALLIS-CHALMERS GARRICK J SOLOVEY	C.F.M.F. BILL DUESING	E.L.H. PUBLICATIONS - THE RADIOACTIVE EXCHANGE EDWARD E HELMINSKI
AMERICAN FRIENDS SERVICE COMMITTEE WILLIAM REYNOLDS	CALIFORNIA DEPT OF CONSERVATION PERRY AMIMITO	E.R. JOHNSON ASSOCIATES INC E R JOHNSON G L JOHNSON
AMERICAN NUCLEAR INSURERS DOTTIE SHERMAN	CALIFORNIA DEPT OF HEALTH SERVICES BEVERLEE MYERS	EAST COMPANY INC RAYMOND PLETZ
APPLIED MECHANICS INC GRAHAM G MLSTOE JOHN R WILLIAMS	CALIFORNIA INSTITUTE OF TECHNOLOGY LEON T SILVER	EAST TENNESSEE STATE UNIVERSITY ALBERT F IGAR
ARGONNE NATIONAL LABORATORY DAVID F FENSTER J HOWARD KITTEL MARTIN SEITZ MARTIN J STEINDLER W S WHITE	CAPITAL AREA GROUND WATER CONSERVATION COMMISSION A N TLRCAN JR	EBASCO SERVICES INC ZUBAIR SALEEM
ARTHUR D. LITTLE INC AVIVA BRECHER CHARLES R HADLOCK	CAPITAL UNIVERSITY VICTOR M SHOWALTER	EDISON ELECTRIC INSTITUTE R E L STANFORD
ATOMIC ENERGY CONTROL BOARD J L WALLACH	CARNEGIE-MELLON UNIVERSITY STEPHEN G ZEMBA	EDS NUCLEAR INC C SUNDARARAJAN
ATOMIC ENERGY COUNCIL KUO YU FH LIU	CASTLE VALLEY ORCHARDS CARL ANDERSON	EG & G IDAHO INC GEORGE B LEVIN M D MCCORMACK T H SMITH RICHARD TALIMAN
ATOMIC ENERGY OF CANADA LTD M O LUKE ANN QUINN F P SARGENT	CAYUGA LAKE CONSERVATION ASSOCIATION INC D S KIEFER	ELECTROWATT ENGINEERING SERVICE H N PATAK
ATOMIC ENERGY RESEARCH ESTABLISHMENT R L NELSON	CENTRAL WASHINGTON UNIVERSITY J R HINTHORNE	ELSAM A V JOSHI
ATOMIC INDUSTRIAL FORUM INC EMANUEL GORDON	CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE RENE HEREMANS	EMBASSY OF THE UNITED STATES (SWEDEN) MALDIT HAJLEN RYLANDER
AUSTRALIAN ATOMIC ENERGY COMMISSION	CHALMERS UNIVERSITY OF TECHNOLOGY BERT ALLARD	ENERCOR INC JOHN RODOSEVICH
BABCOCK & WILCOX INFORMATION SERVICES	CHEM-NUCLEAR SYSTEMS INC ROBIN L DEAI	ENERGY FUELS NUCLEAR INC DON M PILLMOR
BALL ASSOCIATES LTD DOUGLAS BALL	CITIZENS ASSOCIATION FOR SOUND ENERGY JUANITA ELLIS	ENERGY INC
BATTELLE COLUMBUS DIVISION JFFREY L MEANS NEIL E MILLER THOMAS M TRAINER KENNETH R YATES	CITIZENS INSTITUTE FOR A POSITIVE ENERGY POLICY LINDSAY AUDIN	ENERGY RESEARCH LABORATORY HITACHI INC MAKOTO KIKUCHI
BECHTEL GROUP INC THOMAS S BAER DON B CRANDALL LESLIE J JARDINE R C LOVINGTON N A NORMAN L YOUNG PARK RICHARD J TOSETTI	COLUMBIA UNIVERSITY HUBERT STALDIGEL	ENVIRONMENT CANADA CLAUD BARREAU
BENDIX FIELD ENGINEERING CORP JOHN C PACER	CONNECTICUT GOVERNORS OFFICE MARY M HART	ENVIRONMENTAL ANALYSIS LABORATORIES CORP LEON LEVENTHAL
BHABHA ATOMIC RESEARCH CENTRE V SUKUMORAN K T THOMAS	CONSERVATION COUNCIL OF NORTH CAROLINA JANE SHARP	ENVIRONMENTAL POLICY INSTITUTE DAVID M BLEICK FRED MILLAR
BLACK & VEATCH M JOHN ROBINSON	CONSOIL ASSOCIATES DAVID A LEE	ENVIROSPHERE COMPANY BOB HAINES
BRENK SYSTEMPLANUNG H D BRENK	CONVERSE WARD A M HALE	ERIE COUNTY ENVIRONMENTAL MANAGEMENT COUNCIL JOAN P SCHMIDT
BRITISH NUCLEAR FUELS LTD R S WILKS	CORNELL UNIVERSITY JOHN BIRD ROBERT POHL	ERTEC WESTERN INC KENNETH WILSON
BROOKHAVEN NATIONAL LABORATORY M S DAVIS SANDRA G LANE P W LEVY SAMUEL V PANNO PETER SOO HELEN TODOSOW (2)	COUNCIL ON ECONOMIC PRIORITIES MARVIN RESNIKOFF	EXXON NUCLEAR IDAHO COMPANY INC NATHAN A CHIPMAN D L CONDOTTA W B KERR GARY WAYMIRE
	CYGNA ENERGY SERVICES DONALD GARDNER	F.B.A.B. OTTO BROZEV
	DAMES & MOORE RON KEAR O L OZTUNOLI	FENIX & SCISSON INC JOSE A MACFALDO
	DAPPOLONIA CONSULTING ENGINEERS INC LISA K DONOHUE ABBY FORREST AMIRA HAMDY PETER C KELSALL CARL E SCHUBERT	FLORIDA DEPT OF ENVIRONMENTAL REGULATION HAMILTON OVEN
	DAWCON MANAGEMENT CONSULTING SERVICE DAVID A WEBSTER	FLORIDA INSTITUTE OF TECHNOLOGY JOSEPH A ANGELO JR
	DELAWARE CUSTOM MATERIEL INC HOWARD NOVITCH	FLORIDA POWER & LIGHT COMPANY JAMES R TOMONTO

FLORIDA STATE UNIVERSITY
JOSEPH F. DONOGHUE
FLUOR ADVANCED TECHNOLOGY DIVISION
JOAN V. MCCURRY
FLUOR ENGINEERS & CONSTRUCTORS INC
RAYMOND J. DUGAL
VINCENT J. KAVLICK
FORD, BACON & DAVIS UTAH INC
PRESTON H. HUNTER
BURTON J. THAMER
FOSTER-MILLER ASSOCIATES INC
NORBERT PAAS
FREIE UNIVERSITAET BERLIN
HANSKARL BRUEHE
FRIENDS OF THE EARTH
LOUIS BUCKLIN
RENEL PARSONS
GENERAL ATOMIC COMPANY
ROBERT M. BURGOYNE
ROBERT J. CAMPANA
H. C. CARNEY
MICHAEL SIAMATELAKIS
GEO/RESOURCE CONSULTANTS INC
ALVIN K. JOE JR.
GEOLOGICAL SURVEY OF CANADA
LIBRARY
JOHN SCOTT
GEOLOGICAL SURVEY OF DENMARK
L. F. ANDERSEN
GEORGETOWN CONSULTING GROUP
SUSAN SHALAGAN
GEORGIA INSTITUTE OF TECHNOLOGY
GEOFFREY G. EICHHOLZ
ALFRED SCHNEIDER
CHARLES E. WEAVER
GEOTECHNICAL ENGINEERS INC
RICHARD W. TLRNELL
GEOTRANS
JAMES MERCER
GERMANTOWN FRIENDS SCHOOL
HERB BASSOW
GESELLSCHAFT F. STRAHLEN U.
UMWELTFORSCHUNG M.B.H.
WOLFGANG BODE
HANS W. LEVI
GIBBS & HILL INC
ROBERT PRIETO
GILBERT/COMMONWEALTH
JERRY L. ELLIS
GOLDER ASSOCIATES
ELIZABETH EISENHOD
LAWRENCE A. WHITE
CLEMENT M. K. YUEN
GTC GEOLOGIC TESTING CONSULTANTS LTD
JOHN F. PICKENS
GULF STATES UTILITIES COMPANY
JOHN F. BARRY
H & R TECHNICAL ASSOCIATES INC
WILLIAM R. RHYNE
HAHN-MEITNER-INSTITUT FUR
KERNFORSCHUNG BERLIN
KLAUS ECKART MAASS
HANFORD ENGINEERING DEVELOPMENT
LABORATORY
ALBERT G. BLASEWITZ
ROBERT EINZIGER
R. L. KNECHT
W. E. ROAKE
HARDING LAWSON ASSOCIATES
FRANK C. KRESSE
HARVARD UNIVERSITY
DADE W. MOELLER
RAYMOND SIFER

HIRAM COLLEGE
JAMES W. COWDEN
HOUGH-NORWOOD HEALTH CARE CENTER
GEORGE H. BROWN M.D.
IDAHO BUREAU OF MINES AND GEOLOGY
EARL H. BENNETT
CHARLES R. KNOWLES
IDAHO DEPT OF HEALTH AND WELFARE
ROBERT D. FLUNDERBURG
ILLINOIS DEPT OF NUCLEAR SAFETY
MILTON Z. KOR
IMPERIAL COLLEGE OF SCIENCE AND
TECHNOLOGY
B. K. ATKINSON
INSTITUT FUR TRIFLAGERUNG
WERNER BREWITZ
H. GIES
KLAUS KUHN
E. R. SOLIER
PETER LERPMAANN
INSTITUTE FOR CHEMICAL TECHNOLOGY
REINHARD ODOJ
INSTITUTE OF GEOLOGICAL SCIENCES
NEIL A. CHAPMAN
INSTITUTE OF RADIATION PROTECTION
KAI JAKOBSSON
INTERA ENVIRONMENTAL CONSULTANTS INC
LARRY RICKERTSEN
ROBERT WILFMS
INTERNATIONAL ATOMIC ENERGY AGENCY
EVERETT R. IRISH
FRANK A. OHARA
INTERNATIONAL ENERGY ASSOCIATES LTD
BLYTHE K. LYONS
INTERNATIONAL ENERGY SYSTEMS CORP
JOHN A. BOWLES
INTERNATIONAL ENGINEERING COMPANY
INC
TERRY L. STEINBORN
MAX ZASLAWSKY
INTERNATIONAL RESEARCH AND
EVALUATION
R. DANFORD
IOWA STATE COMMERCE COMMISSION
ROBERT J. BUCKLEY
IOWA STATE UNIVERSITY
MARTIN C. EDELSON
J. F. MCCLELLAND
IRT CORP
J. STOKES
ISTITUTO SPERIMENTALE MODELLI E
STRUTTURA S.P.A.
F. GERA
J.F.T. AGAPITO & ASSOCIATES INC
MICHAEL P. HARDY
JACKSON STATE UNIVERSITY
ESTUS SMITH
JAPAN ATOMIC ENERGY RESEARCH INSTITUTE
TARO ITO
HARU TO NAKAMURA
JGC CORPORATION
MASAHICO MAKINO
JOHNS HOPKINS UNIVERSITY
JARED L. COHON
JOINT RESEARCH CENTRE
FRANCESCO GIRARDI
JORDAN GORRILL ASSOCIATES
JOHN D. TEWHEY
KAISER ENGINEERS INC
W. J. DODSON
J. S. RITCHIE

KANSAS DEPT OF HEALTH AND
ENVIRONMENT
GERALD W. ALLEN
KBS
LARS B. NILSSON
KELLER WREATH ASSOCIATES
FRANK WREATH
KERNFORSCHUNGSZENTRUM KARLSRUHE
GMBH
K. D. CLOSS
R. KOSTER
HORST PENTINGHAUS
KIHN ASSOCIATES
HARRY KIHN
KLM ENGINEERING INC
B. GEORGE KNAZIEWICZ
KOREA INSTITUTE OF ENERGY AND
RESOURCES (KIER)
CHOO SEUNG HWAN
KYOTO UNIVERSITY
YORITERU INOUE
LABORATOIRE RENE BERNAS
J. C. DRAN
LAWRENCE BERKELEY LABORATORY
JOHN A. APPS
THOMAS DOE
NORMAN M. EDELSTEIN
BRIAN KANEHIRO
J. WANG
LAWRENCE LIVERMORE NATIONAL
LABORATORY
LYNDEN B. BALLOU
DANA FISHERWOOD
D. D. JACKSON
R. CARROLL MANINGER
LAWRENCE D. RAMSPOTT (2)
FRANK ROGUE
R. N. SCHOCK
W. G. SUTCHIFFE
TECHNICAL INFORMATION DEPARTMENT
L 53
RICHARD VAN KONYNENBURG
LEHIGH UNIVERSITY
D. R. SIMPSON
LOS ALAMOS NATIONAL LABORATORY
ERNEST A. BRYANT
GEORGE A. COWAN
BRUCE R. ERDAI
CLAUDE HERRICK
DONALD T. OAKLEY
K. K. S. PILLAY
ROBERT E. RIECKER
JOE SMYTH
KURT WOLFSBERG
LOS ALAMOS TECHNICAL ASSOCIATES INC
R. J. KINGSBURY
LOS ANGELES PIERCE COLLEGE
SIGMUND P. HARRIS
LOUISIANA DEPT OF TRANSPORTATION &
DEVELOPMENT
GEORGE H. CRAMER II
LOUISIANA GEOLOGICAL SURVEY
SYED HAQUE
LOUISIANA NUCLEAR ENERGY DIVISION
L. HALL BOHLINGER (3)
LOUISIANA TECH UNIVERSITY
LIBRARY
NORMAN WITRIAL
MASSACHUSETTS INSTITUTE OF
TECHNOLOGY
JOHN DELTCH
TED GREENWOOD
RICHARD K. LESTER
MARSHA LEVINE

MCDERMOTT INC
 KAREN L. FLRLOW
MCMASTER UNIVERSITY
 L. W. SHEMILT
MECHANICAL TECHNOLOGY INC
 STANLEY W. DOROFF
MEMBERS OF THE GENERAL PUBLIC
 DAVID H. BOLTZ
 JAMES BOYD
 WILLIAM E. CONAWAY
 STEVE CONWAY
 RALPH DILLER
 BRIAN DOMBROWSKI
 DANNILE D. DI DEK
 RICHARD I. FOLKE
 BARRETT R. FRITZ
 SHIRLEY M. GIFFORD
 DARYL GLAMANN
 OSWALD H. GREAGER
 DOUGLAS H. GREENLEE
 JOAN GREGOR
 C. F. HAJEK
 HAROLD J. JAMES
 D. C. LANGSTAFF
 DAVID LYLL
 MAX MCDOWELL
 A. ALAN MOGHISSI
 ALAN D. PASTERNAK
 SHAILER S. PHILBRICK
 ROGER F. POWERS
 PAUL SHEWMON
 M. J. SZULINSKI
 GORDON THOMPSON
 A. F. WASSERBACH
 JIMMY L. WHITE
MEMORIAL UNIVERSITY OF NEWFOUNDLAND
 JOHN E. GALE
MICHAEL BAKER, JR. INC
 C. J. TOUHILL
MICHIGAN DEPT OF PUBLIC HEALTH
 DON VAN FAROWE
MICHIGAN DISTRICT HEALTH DEPT NO 4
 EDGAR KRIFT
MICHIGAN TECHNOLOGICAL UNIVERSITY
 GARY L. DOWNEY
MINERALOGICAL SOCIETY OF AMERICA
 EDWIN ROEDDER
MISSISSIPPI ATTORNEY GENERALS OFFICE
 MACK CAMERON
MISSISSIPPI CITIZENS AGAINST NUCLEAR DISPOSAL
 STANLEY DEAN FLINT
MISSISSIPPI DEPT OF ENERGY AND TRANSPORTATION
 JOHN W. GREEN (3)
MISSISSIPPI DEPT OF NATURAL RESOURCES
 CHARLES L. BIALOCK
MISSISSIPPI DEPT OF WILDLIFE CONSERVATION
 JOSEPH W. JACOB JR.
MISSISSIPPI EMERGENCY MANAGEMENT AGENCY
 JAMES E. MAHER
MISSISSIPPI STATE BOARD OF HEALTH
 EDDIE S. FUENTE
 J. WARREN GREEN
MISSISSIPPI STATE HOUSE OF REPRESENTATIVES
 JERRY OKEEFE

MITRE CORP
 LESLIE A. ETTINGER
MITSUBISHI METAL CORP
 TATSUO ARIMA
MOBAY CHEMICAL CORP
 KENNETH H. HASHIMOTO
NASA JOHNSON SPACE CENTER
 MICHAEL R. HELFERT
NATIONAL ACADEMY OF SCIENCES
 JOHN T. HOLLOWAY
 PETER B. MYERS
NATIONAL ATOMIC MUSEUM
 GWYN SCHPEINER
NATIONAL BOARD FOR SPENT NUCLEAR FUEL, KARNBRANSLENAMDEN
 NILS RYDELL
NATIONAL BUREAU OF STANDARDS
 RILEY M. CHUNG
 WILLIAM P. REED
NATIONAL SCIENCE FOUNDATION
 ROYAL E. ROSTENBACH
NATIONALE GENOSSENSCHAFT FUR DIE LAGERUNG RADIOAKTIVER ABFALLE
 MARLIES KUHN
NATURAL RESOURCES DEFENSE COUNCIL
 THOMAS B. COCHRAN
NEVADA DEPT OF ENERGY
 ROBERT R. LOUA
NEW ENGLAND NUCLEAR CORP
 KERRY BENNETT
 CHARLES B. MILLIAN
NEW JERSEY DEPT OF ENVIRONMENTAL PROTECTION
 JEANETTE ENG
NEW MEXICO ENVIRONMENTAL EVALUATION GROUP
 ROBERT H. NEILL
NEW YORK DEPT OF HEALTH
 DAVID AXELROD M.D.
NEW YORK STATE ATTORNEY GENERALS OFFICE
 EZRA I. BIALIK
NEW YORK STATE ELECTRIC & GAS CORP
 LEWIS L. STALEY
NEW YORK STATE ENERGY OFFICE
 JOHN P. SPATH (15)
NEW YORK STATE ENVIRONMENTAL FACILITIES CORP
 PICKETT T. SIMPSON
NEW YORK STATE ERDA
 JOHN C. DEMPSEY
NEW YORK STATE GEOLOGICAL SURVEY
 ROBERT H. FAKINDIN
NEW YORK STATE PUBLIC SERVICE COMMISSION
 IRID HAAG
NEW YORK UNIVERSITY MEDICAL CENTER
 MERRIL EISENBLD
NIEDERSACHSISCHES SOZIALMINISTERIUM
 HORST SCHNEIDER
NORTH CAROLINA DEPT OF NATURAL RESOURCES & COMMUNITY DEVELOPMENT
NORTH DAKOTA GEOLOGICAL SURVEY
 DON L. HALVORSON
NORTH ILLINOIS UNIVERSITY
 B. VON ZILLEN
NORTHEAST FOUR COUNTY REGIONAL PLANNING & DEVELOPMENT ORGANIZATION
 JOHN C. PIERSON

NORTHWESTERN UNIVERSITY
 BERNARD J. WOOD
NTR GOVERNMENT SERVICES
 THOMAS V. REYNOLDS
NUCLEAR ASSURANCE CORP
 ANDREW J. FRANKEL
 JOHN V. HOLSTON
 JEAN RION
NUCLEAR ENERGY AGENCY/OECD
 ANTHONY MULLIFF
NUCLEAR INFORMATION AND RESOURCE SERVICE
 GARY HZKOWITZ
NUCLEAR SAFETY RESEARCH ASSOCIATION
 KAZU MORIMATSU
NUCLEAR SYSTEMS ASSOCIATES INC
 CHARLES J. DIVONA
NUCLEAR WASTE WATCHERS
 HELEN LEYARTI
NUS CORP
 W. G. BITTER
 RODNEY J. DAVIS
 JOSEPH J. DINIANO
 BARRY N. NAFT
 DOUGLAS D. ORVIS
 DOUGLAS W. TONKAY
NUTECH ENGINEERS INC
 ALFRED S. GARMAN
 PAUL C. SUN
NWT CORP
 W. L. PEARL
OAK RIDGE NATIONAL LABORATORY
 J. O. BLOMBERG
 H. C. CLAIBORNE
 ALLEN G. CROFT
 LESLIE R. DOLE
 JOHN T. ENSMINGER
 CATHY S. FORE
 C. JOHNSON
 DAVID C. KOCHER
 ELLEN D. SMITH
 E. G. ST. CLAIR
 STEPHEN S. STOW
OFFICE OF NWTs INTEGRATION
 ROBERT E. HEINEMAN
 HARRY W. SMEDES
OHIO DEPT OF ECONOMIC AND COMMUNITY DEVELOPMENT
 ROGER B. WILLIAMS
OHIO ENVIRONMENTAL COUNCIL
 STEPHEN H. SEDAM
OHIO ENVIRONMENTAL PROTECTION AGENCY
 HAROLD W. KOHN
OHIO STATE UNIVERSITY
 R. N. CHRISTENSEN
ONTARIO HYDRO
 R. W. BARNES
 J. A. CHADHA
 K. A. CORNELI
 C. F. IFE
ONTARIO RESEARCH FOUNDATION
 LYDIA M. LUCKEIVICH
OPEN EARTH
 PETER J. SMITH
OREGON DEPT OF ENERGY
 DONALD W. GODARD
OREGON STATE UNIVERSITY
 BRIAN DODD
 U. C. RINGLE
ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
 J. P. OLIVIER

OTHA INC
 JOSEPH A LIEBERMAN
PACIFIC GAS AND ELECTRIC COMPANY
 ADRIAN C SMITH JR
PACIFIC NORTHWEST LABORATORY
 W T BONNER
 DON J BRADLEY
 H C BUKHOLDER
 I I CLARK
 FLOYD N HODGES
 J H JARRETT
 MAX R KREITER
 DONALD E LARSON
 J F MENDEL
 R WILLIAM NELSON
 R E NIGHTINGALE
 J M RUSIN
 R JEFF SERNE
 R E WESTERMAN
 J H WESTSIK JR
**PARSONS, BRINCKERHOFF, QUADE, &
 DOUGLAS INC**
 T C CHEN
 T R KUESSEL
 MARK E STEINER
**PENBERTHY ELECTROMELT INTERNATIONAL
 INC**
 LARRY PENBERTHY
**PENNSYLVANIA GOVERNORS ENERGY
 COUNCIL**
 HERBERT JACOBS
**PENNSYLVANIA OFFICE OF VOCATIONAL
 REHABILITATION**
 ANDREW CHOPAK
PENNSYLVANIA STATE UNIVERSITY
 MICHAEL GRUTZICK
 WILLIAM A JESTER
 WILLIAM B WHITE
 MICHAEL ZOLENSKY
PERRY COUNTY SCHOOLS
 MANILL A COCHRAN
PHYSIKALISCH-TECHNISCHE BUNDESANSTALT
 PETER BRENNERKE
POINT BEACH NUCLEAR POWER PLANT
 GLENN A REED
PORTLAND GENERAL ELECTRIC
 J W TIENTSCH
**POWER AUTHORITY OF THE STATE OF NEW
 YORK**
 MYRON M KACZMARSKY
**POWER REACTOR AND NUCLEAR FUEL
 DEVELOPMENT CORPORATION**
PRESQUE ISLE COURTHOUSE
PROCESS AND ENGINEERING DEVELOPMENT
 GFRALD L RITTEP
PUBLIC SERVICE INDIANA
 ROBERT S WEGENG
QUADREX CORP
 FRANCIS J KENESHEA
RADIAN CORP
 BARBARA MAXEY
RE/SPEC INC
 PAUL F GNIRK
RENSSELAER POLYTECHNIC INSTITUTE
 JAMES WL
RIDIHALGH, EGGERS & ASSOCIATES INC
 PHILIP E EGGERS
RISO NATIONAL LABORATORY
 LARS CARLSEN
ROCKWELL HANFORD OPERATIONS

HARRY BABAD
 G S BARNEY
 R A DEJU
 R J GIMERA
 KARL M LA RUE
 MICHAEL J SMITH
 K THIRU MALAI
 DAVE A TURNER
ROCKWELL INTERNATIONAL
 K V GILBERT
**ROCKWELL INTERNATIONAL ENERGY SYSTEMS
 GROUP**
 HARRY PEARLMAN
 LAWRENCE J SMITH
ROGERS & ASSOCIATES ENGINEERING CORP
 ARTHUR SUTHERLAND
S.E. LOGAN & ASSOCIATES INC
 STANLEY F LOGAN
S.M. STOLLER CORP
 ROBERT W KLIPP
SAN DIEGO GAS & ELECTRIC COMPANY
 LOUIS BERNATH
**SAN JOSE STATE UNIVERSITY SCHOOL OF
 ENGINEERING**
 R N ANDERSON
SANDIA NATIONAL LABORATORIES
 LIBRARY
 G C ALLEN
 JOE A FERNANDEZ
 THOMAS O HINTER
 J KEITH JOHNSTONE
 O E JONES
 R W LYNCH
 MARTIN A MOLECKE
 E J NOWAK
 RICHARD E PEPPING
 G F RUDOLFO
 ALLAN R SATTLER
 LEO W SCULLY
 SCOTT SINNOCK
 A W SNYDER
 A E STEPHENSON
 DANIEL M TALBERT
 WENDELL D WEART
 WIPP CENTRAL FILES
SAVANNAH RIVER LABORATORY
 E J HENNELLY
 CAROL JANTZEN
 WILLIAM R MCDONELL
 S W OREAR SR
 DONALD ORTH
 JOHN A STONE
 S V TOPP
SCIACKY BROTHERS
 JOHN C JASPER
SCIENCE APPLICATIONS INC
 JEFFREY ARBITAL
 JERRY J COHEN
 RALPH FULLWOOD
 JAMES F HAMMELMAN
 RONALD HOFMANN
 J ROBERT LARIVIERE
 DAVID H LESTER
 PETER E MCGRATH
 JOHN E MOSIER
 KRISHAN K WAHI
 ROBERT A YODER
**SCIENTISTS INSTITUTE FOR PUBLIC
 INFORMATION**
 TERRY R LASH

SENECA COUNTY PLANNING BOARD
SHIMIZU CONSTRUCTION COMPANY LTD
 JUNJI TAKAGI
SIERRA CLUB
 EDNA ZEAVIN
SIERRA CLUB - MISSISSIPPI CHAPTER
SIERRA GEOPHYSICS INC
 STEPHEN I GILLET
**SIX-COUNTY COMMISSIONERS
 ORGANIZATION**
 G ALLEN LAWCETT
SOUTH CAROLINA GEOLOGICAL SURVEY
 NORMAN K OLSON
SOUTH DAKOTA GEOLOGICAL SURVEY
 RICHARD BRETZ
SOUTH DAKOTA OFFICE OF ENERGY POLICY
 STEVEN M WEGMAN
SOUTHERN SCIENCE APPLICATIONS INC
 K D KIRBY
**SOUTHWEST RESEARCH AND INFORMATION
 CENTER**
 DON HANCOCK
ST & E TECHNICAL SERVICES INC
 STANLEY M KLAINER
ST DONAVENTURE UNIVERSITY
 CARL J TWAROG
ST MARTIN HIGH SCHOOL
 RAYMOND J WERTHNER
STANFORD UNIVERSITY
 KONRAD B FRALKSOPF
 GEORGE A PARKS
 IRWIN REMSON
STEADMAN & HECTOR, P A
 ALICE G HECTOR
STEARNS-ROGER SERVICES INC
 VFRYL ESCHEN
STONE & WEBSTER ENGINEERING CORP
 PATRICIA ANN O'CONNELL
 J PECK
 ARLENE C POST
STUDSVIK ENERGITEKNIK AB
 AKE HULTGREN
 ROIF SJOBLUM
SUMMIT COUNTY ENVIRONMENTAL SERVICES
 JAMEST KING
SWANSON ENVIRONMENTAL INC
 PETER G COLLINS
SWISS FEDERAL OFFICE OF ENERGY
 U NIEDERER
SYRACUSE UNIVERSITY
 WALTER MEYER
SYSTEM DEVELOPMENT CORP
 RHONNIE L SMITH
SYSTEMS SCIENCE AND SOFTWARE
 PETER LAGUS
T.M. GATES INC
 TODD M GATES
TECHNICAL INFORMATION PROJECT
 DONALD PAY
TECHNICAL RESEARCH CENTRE OF FINLAND
 OLLI J HEINONEN
 SILJA RUMMUKAINEN
 KARI SAARI
 SEppo VUORI
TEKNEKRON RESEARCH INC
 ANTHONY F MOSCATI
TELEDYNE PIPE
 TOBY A MAPLES
TENNESSEE DEPT OF PUBLIC HEALTH
 BILL GRAHAM
TEXAS A & M UNIVERSITY
 ROY W HANN JR

TEXAS BUREAU OF RADIATION CONTROL
 DONALD G. ANDERSON
TEXAS DEPT OF HEALTH
 DAVID K. LACKER
TEXAS ENERGY & NATURAL RESOURCES
ADVISORY COUNCIL
 TERRY BARRON
 CAROL KING
TEXAS HOUSE OF REPRESENTATIVES
 PETE LANEY
THE ANALYTIC SCIENCES CORP
 JOHN W. BARTLETT
 CHARLES M. KOPLIK
 J. W. VOSS
THE JACKSON CLARION-LEDGER
 MARK SCHLEIFSTEIN
TIOGA COUNTY PLANNING BOARD
 PATRICK J. SMYTH
TRANSNUCLEAR INC
 BILL R. TEER
TRENDS PUBLISHING INC
TRINITY EPISCOPAL CHURCH
 BENJAMIN F. BELL
TRW INC
 PETER ALEXANDER
TUN ISMAIL ATOMIC RESEARCH CENTRE
 PUSPATI LIBRARY
U.H.D.E.
 FRANK STEINBRUNN
U.S. ARMY CORPS OF ENGINEERS
 ALAN BUCK
U.S. BUREAU OF LAND MANAGEMENT
 LYNN JACKSON
 EDWARD R. SCHERICK
U.S. BUREAU OF MINES
 GEORGE E. NIEWIADOMSKI
U.S. BUREAU OF RECLAMATION
 REGE LEACH
U.S. DEPT OF ENERGY
 R. COOPERSTEIN
 S. H. GREENLEIGH
U.S. DEPT OF ENERGY - ALBUQUERQUE
OPERATIONS OFFICE
 R. LOWERY
 JOSEPH M. MCGOUGH
 DORNER T. SCHUELER
U.S. DEPT OF ENERGY - CHICAGO
OPERATIONS OFFICE
 PUBLIC READING ROOM
 R. SELBY
U.S. DEPT OF ENERGY - DALLAS SUPPORT
OFFICE
 CURTIS E. CARLSON, JR.
U.S. DEPT OF ENERGY - DIVISION OF WASTE
REPOSITORY DEPLOYMENT
 J. W. BENNETT
 C. R. COOLEY (2)
 WARREN EISTER
 CYRUS KLINGSBERG
 THOMAS P. LONGO
 RALPH STEIN
U.S. DEPT OF ENERGY - HEADQUARTERS
 PUBLIC READING ROOM
U.S. DEPT OF ENERGY - IDAHO OPERATIONS
OFFICE
 JAMES F. LEONARD
 PUBLIC READING ROOM
 J. H. SAKO
 JOHN B. WHITSETT
U.S. DEPT OF ENERGY - MATERIALS SCIENCE
DIVISION
 R. J. GOTTSCHALL

U.S. DEPT OF ENERGY - NEVADA OPERATIONS
OFFICE
 M. P. KUNICH
 PUBLIC READING ROOM
U.S. DEPT OF ENERGY - NUCLEAR
ENVIRONMENTAL APPLICATION BRANCH
 ROBERT W. BARBER
U.S. DEPT OF ENERGY - NWTS PROGRAM
OFFICE
 T. BAILLIEU
 M. BLANCHARD
 L. A. CASEY
 R. LAHOTI
 L. K. MCCLAIN
 J. O. NEFF
 MARJORIE POPOVICH
 K. K. WU
 R. C. WUNDERLICH
U.S. DEPT OF ENERGY - OAK RIDGE
OPERATIONS OFFICE
 PUBLIC READING ROOM
U.S. DEPT OF ENERGY - OFFICE OF BASIC
ENERGY SCIENCES
 MARK W. WITTELS
U.S. DEPT OF ENERGY - OFFICE OF NUCLEAR
FUEL CYCLE
 O. P. GORMLEY
U.S. DEPT OF ENERGY - OFFICE OF PROJECT
AND FACILITIES MANAGEMENT
 D. L. HARTMAN
U.S. DEPT OF ENERGY - OFFICE OF WASTE
ISOLATION
 JOSEPH A. LEARY
 JANIE SHAHEEN
U.S. DEPT OF ENERGY - OFFICE OF WASTE
PRODUCTS
 G. K. OFTEL
 JAMES TURI
U.S. DEPT OF ENERGY - RICHLAND
OPERATIONS OFFICE
 O. L. OLSON
 PUBLIC READING ROOM
 D. J. SQUIRES
U.S. DEPT OF ENERGY - SAN FRANCISCO
OPERATIONS OFFICE
 ENERGY RESOURCES CENTER
 LEN LANNI
 PUBLIC READING ROOM
U.S. DEPT OF ENERGY - SAVANNAH RIVER
OPERATIONS OFFICE
 REGINA T. HARRIS
 T. B. HINDMAN
U.S. DEPT OF ENERGY - TECHNICAL
INFORMATION CENTER (27)
U.S. DEPT OF ENERGY - WIPP PROGRAM
 LAWRENCE H. HARMON
U.S. DEPT OF LABOR
 KELVIN K. WU
U.S. ENVIRONMENTAL PROTECTION AGENCY
 DIVISION OF CRITERIA & STANDARDS
 DONALD HUNTER
 JAMES NEIHEISEL
U.S. GENERAL ACCOUNTING OFFICE
 WILLIAM DAVID BROOKS
U.S. GEOLOGICAL SURVEY - COLUMBUS
 A. M. LA SALA, JR.
U.S. GEOLOGICAL SURVEY - DENVER
 M. S. BEDINGER
 JESS M. CLEVELAND
 RICHARD WADDELL
 ROBERT A. ZIELINSKI

U.S. GEOLOGICAL SURVEY - JACKSON
 GARALD G. PARKER, JR.
U.S. GEOLOGICAL SURVEY - MENLO PARK
 JOHN BREDEHOEFT
 J. BYERLEF
 JACOB RUBIN
U.S. GEOLOGICAL SURVEY - RESTON
 I-MING CHOU
 JOHN ROBERTSON
 EUGENE H. ROSEBOOM, JR.
 PETER R. STEVENS
 DAVID B. STEWART
U.S. HOUSE SUBCOMMITTEE ON ENERGY AND
THE ENVIRONMENT
 MORRIS K. U'DALL
U.S. NUCLEAR REGULATORY COMMISSION
 R. BOYLL
 ENRICO F. CONTI
 MICHAEL C. CULLINGFORD
 J. J. DAVIS
 PAUL F. GOLDBERG
 HIGH-LEVEL WASTE LICENSING BRANCH
 HIGH-LEVEL WASTE TECHNICAL
 LIBRARY
 JOHN B. MARTIN (3)
 JOHN C. MCKINLEY
 HUBERT MILLER
 EDWARD O'CONNELL
 G. W. ROLES
 R. JOHN STARMER
 EVERETT A. WICK
U.S. SENATE COMMITTEE ON ENERGY AND
NATURAL RESOURCES
 WILLIS D. SMITH
UHDE GMBH
 OLINGER
UNC NUCLEAR INDUSTRIES
 ED POWERS
UNION CARBIDE CORP
 DENNIS J. FENNELLY
 BLYNN E. PRINCE
UNION OF CONCERNED SCIENTISTS
 MICHAEL FADEN
UNITED KINGDOM DEPT OF THE
ENVIRONMENT
 F. S. FEATES
 RADIOACTIVE WASTE MANAGEMENT
 DIVISION
UNITED STATES GYPSUM COMPANY
 T. L. ROSENSTIEL
UNIVERSITY OF ALBERTA
 F. W. SCHWARTZ
UNIVERSITY OF ARIZONA
 JAAK DAEMEN
 JAMES G. MCCRAY
 ROY G. POST
UNIVERSITY OF CALIFORNIA AT BERKELEY
 NEVILLE G. W. COOK
 THOMAS H. PIGFORD
UNIVERSITY OF CALIFORNIA AT LOS ANGELES
 D. OKRENT
UNIVERSITY OF CALIFORNIA AT RIVERSIDE
 LEWIS COHEN
 DON STIERMAN
UNIVERSITY OF CALIFORNIA AT SAN DIEGO
 RICHARD J. WILLIS
UNIVERSITY OF CINCINNATI
 ATTILA KILINC
UNIVERSITY OF DELAWARE
 FRANK A. KULACKI

UNIVERSITY OF FLORIDA
 DAVID L. CLARK
 DOLORES C. JENKINS
UNIVERSITY OF HAWAII AT MANOA
 DAVID EPP
UNIVERSITY OF ILLINOIS AT URBANA -
CHAMPAIGN
 DANIEL F. HANG
 ALBERT J. MACHIELS
 MAGDI RAGHEB
UNIVERSITY OF LOWELL
 JAMES R. SHEFF
UNIVERSITY OF LULEA
 JAN NILSSON
UNIVERSITY OF MARYLAND
 MARVIN ROLSH
UNIVERSITY OF MINNESOTA
 J. K. TYLKO
UNIVERSITY OF MISSISSIPPI
 GEORGE D. BRUNTON
UNIVERSITY OF MISSOURI AT KANSAS CITY
 EDWIN D. GOEBEL
UNIVERSITY OF MISSOURI AT ROLLA
 ARVIND KUMAR
 NICK TSOLIFANIDIS
UNIVERSITY OF MODENA
 M. ANTONINI
UNIVERSITY OF NEVADA AT RENO
 BECKY WEIMER
UNIVERSITY OF NEW MEXICO
 DOUGLAS G. BROOKINS
UNIVERSITY OF NOTRE DAME
 JOHN LUCEY
UNIVERSITY OF OKLAHOMA
 DANIEL T. BOATRIGHT
UNIVERSITY OF PITTSBURGH
 B. L. COHEN
UNIVERSITY OF RHODE ISLAND
 EDWARD P. LAINE
UNIVERSITY OF SOUTHERN MISSISSIPPI
 CHARLES R. BRENT
 JAMES W. PINSON
 GARY L. WILDMAN
UNIVERSITY OF TENNESSEE AT KNOXVILLE
 J. B. FUSSELL

UNIVERSITY OF TEXAS AT AUSTIN
 EARNEST F. GLOYNA
 JOE D. LEDBETTER
UNIVERSITY OF TEXAS AT SAN ANTONIO
 DONALD R. LEWIS
UNIVERSITY OF TOKYO
 RYOMEI KIYOSE
UNIVERSITY OF UTAH MEDICAL CENTER
 JAMES A. SORENSON
UNIVERSITY OF UTAH RESEARCH INSTITUTE
 LIBRARY
 DUNCAN FOLEY
UNIVERSITY OF WASHINGTON
 DAVID BODANSKY
 M. A. ROBBIN
UNIVERSITY OF WESTERN ONTARIO
 WILLIAM S. FYLE
 P. W. M. JACOBS
UNIVERSITY OF WISCONSIN
 B. C. HAINSON
UNIVERSITY OF WISCONSIN AT FOND DU LAC
 JOHN B. HEIL
UNIVERSITY OF WISCONSIN AT MILWAUKEE
 HOWARD PINCUS
UTAH BUREAU OF RADIATION CONTROL
 DARRELL M. WARREN
UTAH GEOLOGICAL AND MINERAL SURVEY
 MAGE YONETANI
UTAH SOUTHEASTERN DISTRICT HEALTH
DEPARTMENT
 ROBERT L. FLEW
UTILITY DATA INSTITUTE
 FRED YOST
VANDERBILT UNIVERSITY
 FRANK L. PARKER
VEPCO
 D. C. YOUNG
VERMONT AGENCY OF ENVIRONMENTAL
CONSERVATION
 CHARLES A. RATTE
VERMONT STATE NUCLEAR ADVISORY PANEL
 VIRGINIA CALLAN
VIRGINIA DEPT OF HEALTH
 ROBERT G. WICKLIN
VIRGINIA DIVISION OF MINERAL RESOURCES
 ROBERT C. MILICI

VIRGINIA MILITARY INSTITUTE
 HENRY D. SCHREIBER
VIRGINIA POLYTECHNIC INSTITUTE AND
STATE UNIVERSITY
 WALTER HIBBARD
WASHINGTON DEPT OF SOCIAL AND HEALTH
SERVICES
 T. STRONG
WASHINGTON HOUSE OF REPRESENTATIVES
 RAY ISAACSON
WATTLAB
 BOB E. WATT
WAYNE STATE UNIVERSITY
 JAMES A. WOODYARD
WBAL-FM
 WARREN LIEBOLD
WEST DADE REGIONAL LIBRARY
 LOURDES BLANCO LOPEZ
WEST VALLEY NUCLEAR SERVICES COMPANY
INC
 RICHARD M. WINAR
WEST VIRGINIA GEOLOGICAL AND
ECONOMIC SURVEY
 ROBERT B. ERWIN
WESTINGHOUSE ELECTRIC CORP
 GEORGE V. B. HALL
 CAROL A. KIZIS
 GEORGE P. SABOL
 J. R. SCHORNHORST
WESTINGHOUSE WIPP PROJECT
 WESTINGHOUSE ELECTRIC
 CORPORATION
WISCONSIN DEPT OF NATURAL RESOURCES
 DUWAYNE F. GEBKEN
WISCONSIN DIVISION OF STATE ENERGY
 ROBERT HALSTEAD
WISCONSIN GEOLOGICAL AND NATURAL
HISTORY SURVEY
 MICHAEL G. MLDREY JR
 MEREDITH E. OSTROM
WISCONSIN PUBLIC SERVICE CORP
 PAUL WOZNIAK
WOODWARD-CLYDE CONSULTANTS
 ASHOK PATWARDHAN
 WESTERN REGION LIBRARY
WP-SYSTEM AB
 IVAR SAGEFORS
WYOMING GEOLOGICAL SURVEY
 DANIEL N. MILLER
YALE UNIVERSITY
 BRIAN SKINNER