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**SUMMARY OF KEY DIRECTIVES
GOVERNING PERMANENT DISPOSAL
IN A GEOLOGIC REPOSITORY**

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EXECUTIVE SUMMARY

This document was developed in support of the Idaho National Engineering Laboratory (INEL) Spent Fuel and Waste Management Technology Development Program (SF&WMTDP). It is largely comprised of flow diagrams summarizing the key regulatory requirements which govern permanent disposal in a geologic repository. The key purposes are (1) to provide an easy and effective tool for referencing or cross referencing federal directives (i.e., regulations and orders), (2) to provide a method for examining the requirements in one directive category against the requirements in another, and (3) to list actions that must be taken to ensure directive compliance. The document is categorically broken down into a Transportation section and a Mined Geologic Disposal System (MGDS) section to ensure that the interrelationship of the entire disposal system is considered.

The Transportation section describes the transportation packaging requirements, testing methods, and safety requirements imposed on fissile material shipments.

The MGDS section encompasses technical aspects involved in siting, licensing, waste interaction with the container, container design features, physical characteristics of the surrounding environment, facility design features, barrier systems, safety features, criticality considerations, migration restrictions, implementation guidelines, and so forth. Whether the hazardous waste requirements of 40 CFR 260-270 will apply to geologic disposal of some materials is not clear at this time; as this issue is developed, this summary will be revised accordingly. For purposes of illustration, the worst case scenario (i.e., that a permit and a variance will be required for disposal) is outlined (a discussion of the permitting process is not included).

It is important that the approaches and considerations contained in this document be integrated into the efforts of the SF&WMTDP so that every applicable aspect of the regulatory requirements can be evaluated to avoid investing large sums of money into projects that do not take into account all of the aspects of permanent waste disposal. Not until an overall picture and clear understanding of these regulations is established can a basis be developed to govern the direction of future activities of the SF&WMTDP.

1.0 General Introduction

This document summarizes federal directives impacting disposal at a geologic repository. The intention here is three-fold: (1) to provide a tool for referencing current directive requirements, (2) to provide a method for examining the requirements in one directive category against the requirements in another, and (3) to list actions that must be taken to ensure directive compliance. This document will require periodic reviews and updates to reflect changes in applicable directives. The directives discussed herein have been divided into Transportation Requirements and Mined Geologic Disposal System (MGDS) Requirements. Figure 1 provides a visual summary of the requirements necessary for the permanent disposal in a geologic repository.

Flow diagrams, comprising the bulk portion of this document, have been prepared on various levels of detail; the objective is to provide sufficient detail in the flow diagrams so that they can stand alone from the sources of the requirements in most instances. For directives containing large amounts of detailed information, several flow diagrams have been prepared. These descriptions include a summary sheet outlining the information found in the particular regulation or DOE Order. Whenever possible, detailed flow diagrams are developed for all of the subparts contained in each directive.

Each flow sheet is organized into a series of columns: Compliance Approach (listing overall methods for assessing compliance with a particular regulatory requirement); Compliance Support (listing the specific items or topics addressed in that regulation); and Considerations, Information Needs, and Activities (summarizing the significant details covered by that specific regulation or section). Suppose, for example, it is necessary to find applicable directives pertaining to transportation. The Compliance Approach and Support columns would be scanned for transportation related issues resulting in a listing of specific information and directives applicable to the transportation.

It is important that these approaches and considerations be integrated into the activities of the SF&WMTDP so that every applicable requirement can be evaluated to avoid investing large sums of money into projects that do not take into account the long term goal of permanent waste disposal. Not until an overall picture of the applicable directives is established can a basis be developed to govern the direction of future activities of the SF&WMTDP.

Figure 1
Pictorial Summary of
Requirements Developed

FIGURE1.GCD
Rev 12/29/93
Print Scale 6.5:1

1.1 Congressional Actions Impacting Geologic Disposal

In 1954, Congress passed the Atomic Energy Act (AEA) to assure proper management of source, special nuclear, and byproduct material. Section 161 of AEA provided the authority to establish "by rule, regulation, or order, such standards and instruction to govern the possession and use of special nuclear material, source material, and byproduct material as the Atomic Energy Commission may deem necessary or desirable to promote the common defense and security or to minimize danger to life or property." As a result, subsequent Congressional actions have been taken to address the long-term disposal of high-level radioactive waste, resulting in the establishment of such rules, regulations, and orders necessary to ensure compliance with federal legislation. Actions dealing with high-level waste (HLW) disposal include:

Energy Reorganization Act of 1974;

Nuclear Waste Policy Act (NWPA) of 1982;

Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments, which include Land Disposal Restriction (LDR), of 1984;

Nuclear Waste Policy Amendments Act (NWPAA) of 1987;

Federal Facilities Compliance Act (FFCA) of 1992; and

Energy Policy Act of 1992.

1.2 Key Provisions of Applicable HLW Laws

Energy Reorganization Act

Nuclear Regulatory Commission (NRC) licenses DOE HLW disposal.

Nuclear Waste Policy Act and Amendments

Yucca Mountain site is the only one to be characterized to determine suitability.

Capacity of first repository limited to 70,000 metric tonnes of heavy metal for *spent fuel* and equivalent DOE HLW.

Monitored Retrievable Storage (MRS) Facility cannot be constructed until after the NRC has issued a license for the repository.

Congress to evaluate after 2007 of the need for a second repository.

NRC 10 CFR 60 to establish the licensing requirements for the repository.

EPA 40 CFR 191 to establish the standard for HLW and *spent fuel* disposal.

NRC Regulation 10 CFR 60

Waste retrievability during operation and 50 yrs after repository closure.

Pre-emplacement groundwater travel time of > 1000 yrs to accessible environment.

Substantially complete containment of HLW in waste package for 300-1000 yrs.

Limited release rate of radionuclides from waste package after 1000 yrs not to exceed 1 part in 100,000 per year of inventory at 1000 yrs.

Other waste package criteria to avoid in-situ chemical, physical or nuclear interactions which could compromise the performance of the repository.

EPA Standard 40 CFR 191 (Under re-evaluation for HLW by NAS)

Disposal system shall not cause annual dose equivalent to any person in the accessible environment to exceed 25 mrem whole body or 75 mrem critical organ.

Release of radionuclides to accessible environment over 10,000 yrs limited to prescribed values given in paragraph 13 of standard.

Additional requirements to provide additional assurance that standard will be met including institutional controls, monitoring, permanent markers and records, engineered and natural barriers, and avoidance of areas with mined resources.

1.3 Regulation Development

Under the NWPA, a process for the selection of sites for HLW repositories is established, and the DOE is charged with the responsibility of locating, constructing, operating, closing, and decommissioning repositories. This Act also stipulates that the disposal of waste be governed by an environmental standard established by the EPA. Responsibility for assuring that the DOE repository meets this EPA established standard is delegated to the NRC.

In 1983, the NRC developed a procedure for assuring that future repository

investigations and developments are in compliance with the requirements of the NWPA. This procedure was documented under Title 10 of the Code of Federal Regulations, Chapter 60 (10 CFR 60). This regulation currently requires that the standard established in 40 CFR 191 must be met and, in addition, sets numerical requirements for the performance of some repository elements. In the license application, DOE must illustrate that the repository will comply with both of the above regulations.

Because of the requirements placed on the DOE by 10 CFR 60, DOE established a regulation to provide general guidelines for the recommendation of sites for nuclear waste repositories. This regulation was documented in 1984 under Title 10 of the Code of Federal Regulations, Chapter 960. This regulation established procedural guidelines for implementing the requirements set forth in 10 CFR 60, including siting evaluation, nomination, and characterization; filing recommendations for repository development; and preclosure and postclosure guidelines.

The Department of Transportation (DOT) has also established regulations imposed on the DOE pertaining to the safe transportation of radioactive material. As a practical matter, these regulations become valid compliance issues influencing the development of the repository investigations required by the NWPA. Regulations stipulating that a package meeting repository requirements will automatically satisfy applicable transportation requirements do not exist; therefore, a repository packaging must be evaluated against both sets of regulations.

The EPA standard referred to above was promulgated in 1985 under Title 40 of the Code of Federal Regulations, Chapter 191 (40 CFR 191). This standard requires that any repository must protect the public from significant radiation doses for at least 10,000 years after permanent closure by releasing less than a predetermined amount of each radionuclide to the biosphere.

The regulatory requirements relating to the permanent disposal of HLW in a geologic repository are illustrated in Figure 2 and are listed according to the agency which imposes those regulations.

Figure 2
Regulations Affecting Repository Development
by Imposing Agency

Note: The dashed line going to the DOT regulations indicates their indirect nature.

In an effort to assure compliance with these, and any other requirements (including requirements existing prior to the NWPA) having applicability to the permanent geologic disposal of HLW, the DOE imposes specific requirements and procedures in the form of DOE Orders. Applicable DOE Orders have been explained in the flow diagrams contained in their respective sections of this document.

In addition to Regulations and Orders, various guidance exists outlining specific procedures and practices for ensuring compliance with requirements of these directives. These guidance consist of notices, guidelines, memoranda, internal procedures, and implementation procedures. Because this document is a summary, only applicable Regulations and Orders have been summarized in the flow diagrams.

However, a brief listing of some potentially applicable Regulatory Guides is included in Appendix A. The words "potentially applicable" are used here because no detailed investigation into the applicability of these guides has been conducted.

2.0 Transportation Requirements

Although it is the responsibility of the individual shipper to verify compliance with packaging and shipping regulations and to ensure that waste disposal canisters meet MGDS requirements, understanding these requirements will help ensure that the waste canisters that we produce or purchase are in compliance with applicable regulations. Section 2 focuses on analyzing the packaging requirements, package testing methods, and safety requirements imposed on fissile material shipments.

The type of package used is dependent on the activity of the radioactive material being considered. Type A packages cannot exceed A1 or A2 activity limits and are subject only to normal conditions of transport testing. Type B packages may exceed A1 or A2 activity limits and, therefore, require additional hypothetical accident conditions of transport testing. A table of these activity limits for single radionuclides and methods for calculating these activity limits for radionuclides not listed in the table (or for radionuclide mixtures) are contained in subsections 173.435 and 173.433, respectively, of Title 49 of the Code of Federal Regulations, subpart I of Part 173. According to the INEL Roadmap document, SNF will always contain fissile material in excess of these activity limits, thus requiring Type B packaging.

2.1 Listing of Regulations and Orders Developed

- 10 CFR 71 - Packaging and Transportation of Radioactive Material
 - Subpart E - Package Approval Standards
 - Subpart F - Package and Special Form Tests
- 49 CFR 173 - Shippers - General Requirements for Shipments and Packages (flow diagram listing sections developed)
 - Subpart I - Radioactive Materials (Summary)
 - Sections: - Type A or B Package Classification Method
 - Cask/Canister Requirements & Material Specific Restrictions
 - Limitations and Transportation Requirements
 - Fissile Material Requirements
 - Testing Requirements
- 49 CFR 174 - Carriage by Rail
 - Subpart K - Detailed Requirements for Radioactive Materials
- 40 CFR 263 - Standards Applicable to Transporters of Hazardous Materials
- DOE Order 1540.1A - Materials Transportation and Traffic Management

- DOE Order 1540.2 - Hazardous Materials Packaging for Transportation -
Administrative Procedures
- DOE Order 5480.3 - Safety Requirements for Packaging and Transportation
of Hazardous Materials, Substance, or Waste
- DOE-ID 5480.3 - Hazardous Materials Packaging and Transportation
Safety Requirements
 - Attachment 1 - Chapter I - Off-site Shipments
 - Attachment 1 - Chapter II - On-site Shipments

2.2 Flow Diagrams for Regulations and Orders

Flow diagrams are in the order listed in section 2.1.

10 CFR 71 Packaging and Transportation of Radioactive Material

10CFR71.000
Rev. 11/17/93

GOVERNING REGULATION

Subparts

* indicates that a flow diagram for this subpart has been developed.

10 CFR 71 Subpart E Package Approval Standards

WCP/TE/ECO
rev 10/7/88

10 CFR 71 Subpart F Package and Special Form Tests

UCPR71F BOD
rev 9/77/98

**49 CFR 173 Shippers - General Requirements
for Shipments and Packages
Subpart I - Radioactive Materials
Flow Diagram Listing**

49078.000
rev. 10/7/96

49 CFR 173 Shippers - General Requirements for Shipments and Packages Subpart I - Radioactive Materials (Summary)

49CFR 173.900
rev 10/00/00

49 CFR 173 Shippers - General Requirements for Shipments and Packages

Subpart I - Radioactive Materials

Type A or B Package Classification Method

49CFR173.1 GCD
rev 11/20/93

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NOTE: SNF will always be a greater than Type A quantity and contain fissile materials, thus requiring Type B shipping container.

49 CFR 173 Subpart I Cask/Canister & Content Specific Requirements

49CFR173-900
Rev. 11/17/83

49 CFR 173 Subpart I Limitations and Transportation Requirements

49CFR173.000
REV 10/17/93

Considerations,
Information
Needs &
Activities

Governing
Regulation

Regulatory
Requirements

Compliance
Approach

Compliance
Support

49 CFR 173 Subpart I Fissile Material Requirements

49CFR173.000
Rev. 10/17/03

49 CFR 173 Subpart I Testing Requirements

490718ELC008
REV 10/04

49 CFR 174 - Carriage by Rail

Subpart K - Detailed Requirements for Radioactive Materials

49CFR174.000
rev 10/03

40 CFR 263 - STANDARDS APPLICABLE TO TRANSPORTERS OF HAZARDOUS WASTE

40CFR263.GCD
rev 11/17/88

DOE Order 1540.1A - Materials Transportation and Traffic Management

DIS4803.GCD
rev 11/17/92

DOE Order 1540.2 - Haz. Mat. Packaging for Transport - Administrative Procedures

DOE 1540.2.OCD
rev. 11/17/93

GOVERNING REGULATION

Subparts

DOE Order 5480.3 - Safety Requirements for Packaging & Transportation of Hazardous Material, Substance, or Waste

DO54803.GCD
rev 10/17/83

DOE-ID 5480.3 - Haz. Mat. Packaging and Trans. Safety Req.

Attachment 1 - Chapter I: Off-site Shipments

DOE-4003.GCD
REV. 11/17/99

DOE-ID 5480.3 - Haz. Mat. Packaging and Trans. Safety Req.

Attachment 1 - Chapter II: On-site Transfers

DIS-40632.0CD
rev. 11/17/89

3.0 MGDS Requirements

Under Title 40 of the Code of Federal Regulations, section 191 (40 CFR 191), all Mined Geologic Disposal Sites (MGDS) "shall be designed to provide a reasonable expectation, based on performance assessments (PA), that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal" will not exceed the release limits outlined in 40 CFR 191.13. A Performance Assessment, as defined, "(1) identifies the processes and events that might affect the disposal system; (2) examines the effects of these processes and events on the performance of the disposal system; and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events." With this in mind, section 3 summarizes the regulatory requirements for conducting a PA and outlines the nuclear waste packaging requirements that will ensure compliance with both the transportation requirements (discussed in Section 2.0) and MGDS restrictions.

A summary of general aspects that must be accounted for in the development of PA models (or other analysis methods) has been included as the first flow diagram in section 3.2; this is an overall summary of the key performance factors that are addressed throughout the regulations in this section. Other flow diagrams encompass the technical aspects involved in siting, licensing, release limits, waste interactions with the container, container design features, physical characteristics of the surrounding environment, facility design features, barrier systems, safety features, implementation guidelines, migration restrictions, criticality considerations, model verification methods, and so forth.

Since many of the factors influencing the long-term performance of a MGDS are site-specific, a complete assessment of the long-term performance of waste in the MGDS cannot be conducted until after an actual site has been selected and fully characterized for repository development. This section is intended to aid in the modeling development for a hypothetical geologic repository, accounting for as many factors as possible, until such time when an actual MGDS is identified.

3.1 Listing of Regulations and Orders Developed

Summary of General Aspects Implied by Performance Assessment Modeling & Analysis Compliance Approach

- 10 CFR 60 Disposal of High Level Radioactive Waste in Geologic Repositories
 - Subpart B - Licenses (Summary)
 - Sections: - Licenses Compliance Structure
 - Construction Authorization & Permanent Closure Compliance Structure

Subpart E - Technical Criteria (Summary)

Sections: - Performance Objectives & Waste Package Design Compliance Structure
- Operations Area Design Specifications Compliance Structure

10 CFR 960 General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories
Subpart B - Implementation Guidelines
Subpart C - Postclosure Guidelines (flow diagram)
- Postclosure Technical Guidelines Table
Subpart D - Preclosure Guidelines (flow diagram)
- Preclosure Technical Guidelines Table

40 CFR 191 Subpart B - Environmental Standards for the Uranium Fuel Cycle Compliance Structure

40 CFR 264 Subpart X - Permit for Misc. Unit Compliance Structure

40 CFR 268.6 Land Disposal Restriction Compliance Structure

10 CFR 20 Standards for Protection Against Radiation

DOE Order 5820.2A - Radioactive Waste Management (Update in process):
Chapter I - High Level Waste;
Section 3d - Disposal Requirements

3.2 Flow Diagrams for Regulations and Orders

Flow diagrams are in the order listed in section 3.1.

Summary of General Aspects Implied by Performance Assessment Modeling & Analysis Compliance Approach

PAPM 002
REV 10/1983

NOTE: Performance Assessment Modeling & Analysis, when used as a Compliance Approach in flow diagrams indirectly implies all of the above aspects. Supporting requirements in these areas are covered by the flow diagrams for the specific regulations in which these aspects are contained.

10 CFR 60 DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

WCFR60.GCD
REV 11/21/83

* indicates that a flow diagram for this subpart has been developed.

10 CFR 60 Subpart B Licenses Compliance Structure (Summary)

WOFRA00.DDD
rev 11/2/93

10 CFR 60 Subpart B Licenses Compliance Structure

DOE/EA-1003
Rev. 10/2/93

10 CFR 60 Subpart B Construction Authorization & Permanent Closure Compliance Structure

10CFR60.000
Rev. 12/29/93

10 CFR 60 Subpart E Technical Criteria Compliance Structure (Summary)

10CFR 60.600
Rev. 11-21-93

10 CFR 60 Subpart E Technical Criteria - Performance Objectives & Waste Package Design Compliance Structure

MOOSE-SCC
Rev. 12/25/93

10 CFR 60 Subpart E Technical Criteria - Operations Area Design Specifications Compliance Structure

WORKSHEET
NO. 123456

10 CFR 960 General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories

1000000000
101 10/20/94

Governing
Regulation

Subparts

* Indicates that a flow diagram for this subpart has been developed

10 CFR 960 Subpart B Implementation Guidelines

HC4086.BCD
Rev. 11/20/99

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10 CFR 960 Subpart C Postclosure Guidelines

WCP0401000
100 TVR/98

10 CFR 960 Subpart C Postclosure Technical Guidelines Table

Technical Guidelines	Qualifying Condition	Favorable Condition	Potentially Adverse Conditions	Disqualifying Conditions
Geohydrology 960.4-2-1	The present and expected geohydrologic setting compatible w/waste containment & isolation. Must comply w/ requirements of section 960.4-1 for radionuclide accessible environment releases & 10 CFR 80.113 for releases from engineered-barrier system.	Pre-waste-emplacment ground water travel time from disturbed zone to accessible environment < 10,000 yrs; Hydrologic processes during Quaternary Period not affect repository during next 100,000 yrs; stratigraphic, structural & hydrologic features easily & accurately modeled; Saturated & unsaturated zone disposal reqs	Geohydrologic changes such as changes in hydraulic gradient, hydraulic conductivity, effective porosity, ground-water flux w/in host rock; Ground-water source for irrigation or untreated human consumption along flow paths from host rock; Presence of geologic setting of stratigraphic features - difficulty in modeling	Disqualified if pre-waste-emplac. ground-water travel time from disturbed zone to accessible environment expected to be < 1,000 yrs along any pathway of likelihood & significant radionuclide travel
Geochemistry 960.4-2-2	Above condition w/ consideration of likely chemical interactions among radionuclides, host rock, & ground-water	Nature & rates of geochemical processes during Quaternary Period not affect repository in next 100,000 yrs; Geochem cond promoting precipitation, etc; While trans of radionucl. by particulate etc; Water flow allowing < 0.001 %/yr total radionucl. inventory @ 1,000 yrs dissolve; process dec. probable, cum. rel. by factor of 10	Ground-water cond. in host that could affect solubility or chem reactivity of engineered-barrier; Geochem. processes reducing sorption of radionucl. or degrade the rock; Pre-waste-emplacment ground-water cond. in host that are chemically oxidizing	none
Rock characteristics 960.4-2-3	Present & expected character of host rock & surrounding units accommodate thermal, chemical, mechanical, & radiation stresses induced by const. operation, & closure by expected interactions among waste, host, engineered components, & ground-water; Must also comply w/ above restrictions on releases	Host sufficiently thick & laterally extensive to allow flexibility in selecting depth, configuration, & location of repository to ensure isolation; Host with high thermal conductivity, low thermal expansion coeff., or sufficient ductility to seal fractures induced by repository construction, operation, & closure or waste interaction	Rock cond. requiring measures beyond available technology to ensure waste containment; Potential for phenomena such as thermally induced fractures, brine migration, etc affecting isolation; Combination of geologic structural, geochem. & thermal properties, & hydrologic cond. in host, as waste heat gen. dec. isolation	none
Climatic changes 960.4-2-4	Future climatic changes not likely to lead to radionuclide releases < allowable in above; DOE will consider global, regional, & site climatic patterns during Quaternary Period considering geomorphic evidence of climatic conditions in geologic setting	Surface-water system such that expected climatic cycles over next 100,000 yrs not affect waste isolation; Geologic setting in which climatic changes during Quaternary Period had little effect on hydrologic system	Evidence that water table could rise sufficiently over next 10,000 yrs to saturate facility in previously unsaturated host; Evidence that climatic changes in next 10,000 yrs could cause perturbations in effect, porosity, hydraulic gradient/conductivity, or ground-water flux in host increasing transport of radionucl.	none
Erosion 960.4-2-5	Facility placed at depth so that surface erosion not likely lead to releases < above restriction; DOE will consider climatic, tectonic, & geomorphic evidence of rates & patterns of erosion during Quaternary Period	Site cond. that permit waste emplacement at depth at least 300 m below directly overlying surface; Geologic setting where processes during Quaternary Period have < 1 chance in 10,000 over next 10,000 yrs of leading to radionuclide releases; Site cond. so waste exhumation not expected to occur in first million yrs	Geologic setting shows evidence of extreme erosion during Quaternary Period; Geologic setting where nature & rates of geomorphic processes during Quaternary Period could affect ability to isolate waste for first 10,000 yrs after closure	Disqualified if site conditions do not allow portions of underground facility to be situated at least 300 m below directly overlying surface
Dissolution 960.4-2-6	Site located so any subsurface rock dissolution will not lead to releases > restriction above; In predicting likelihood of dissol. DOE will consider evidence of dissolution w/in setting during Quaternary Period, including dissolution vents or other identified features	No evidence that host rock w/in site was subject to significant dissolution during Quaternary Period	Evidence of dissolution w/in geologic setting - such as breccia pipes, dissolution cavity, significant vol. reduction of host or surrounding strata, or any structural collapse - such that a hydraulic interconnection leading to a loss of waste isolation could occur	Disqualified if it is likely that active dissolution would result in a loss of waste during the first 10,000 yrs after closure
Tectonics 960.4-2-7	Future tectonic processes not likely lead to releases < allowed above; In predicting likelihood of disruptive events, DOE will consider structural, stratigraphic, geophysical, & seismic evidence for nature & rates of tectonic processes during Quaternary Period	Nature & rates of igneous activity & tectonic processes during Quaternary Period would, if continued, have < 1 change in 10,000 of leading to radionuclide releases in the first 10,000 yrs after closure	Evidence of active folding, uplift, faulting, etc during Quaternary Period; Historical earthquakes w/ in geologic setting of magnitude affecting isolation upon recurrence; Evidence of increase in freq. of magnitude of future earthquakes; Potential for natural phenomena such as landslides, volcanic act., Potential for tectonic deformation	Disqualified if, based on record-keeping during Quaternary Period, the nature & rates of fault movement or other ground movement are such that loss of isolation is likely to occur
Human interference 960.4-2-8	Site located such that activity of future generations at or near the site will not likely affect the waste containment/isolation; DOE will consider estimated effectiveness to permanent markers & records required by 10 CFR 80 taking into account below two considerations (resources & ownership)	none	none	none
Natural resources 960.4-2-8-1	Considering permanent markers & records, & reasonable projection of value, scarcity, & technology, the natural resources (including water used for irrigation or human consumption w/o treating) would not give rise to interfering activity leading to releases < specified above	No unknown natural resources that have or are projected to have foreseeable value great enough for commercial extraction; Ground water w/ 10,000 ppm or more dissolved solids along any path of likely radionuclide travel from host rock to accessible environment	Indications that site contains naturally occurring materials identified as feasible for future economic extraction; Evidence of subsurface mining/extraction for resources, or drilling other than for evaluating depth w/in site; Evidence to significant conc. of naturally occurring material not widely avail. from other sources	Disqualified if prev. exploration, mining, or extraction activities for resources of commercial importance have created paths between projected facility & accessible environment; Ongoing or future activities to recover mineral resources outside controlled areas expected to lead to loss of isolation
Site Ownership & Control 960.4-2-8-2	Site located on land which DOE can obtain in accordance w/req. 10 CFR 80, ownership, surface & subsurface rights, and control access required in order that surface & subsurface activities will not likely allow releases < specified above	Present ownership and control of land and all surface and subsurface rights by the DOE	Projected land ownership conflicts that can't successfully be resolved through voluntary purchase-sell agreements, non-disputed agency-to-agency transfer of title, or Federal condemnation proceedings	none

NOTE: Additional information in all of these areas located in Appendix IV.

10 CFR 960 Subpart D Preclosure Guidelines

10CFR960.1.600
rev. 11/21/92

10 CFR 960 Subpart D Preclosure Technical Guidelines Table

Revised 2000
10/10/00

	Technical Guideline	Qualifying Condition	Favorable Condition	Potentially Adverse Conditions	Disqualifying Conditions
Preclosure Technical Guideline	Population density and distribution 960.5-2-1	During repository operation and closure, the expected average radiation dose to public w/in any highly populated, or dose rate to any member, not likely exceed a fraction of the limit specified in 960.5-1(a)(1)	Low pop. density in general region of the site; remoteness of site from highly populated areas	Highly residential, seasonal, or daytime population density w/in projected site boundaries; any surface facility located adjacent to area 1 square mile having population not < 1,000 members enumerated by most recent U.S. census	Disqualified if any surface facil. located in highly pop. area or adjacent to 1 square mile area w/ pop. > 1,000; DOE could not develop emergency preparedness prog. set in DOE Order 5500.3
	Site ownership and Control 960.5-2-2	Located on land which DOE can obtain ownership, surface & subsurface rights, & control of access required so that surface & subsurface activities not likely to lead to releases in restricted area > restrictions 960.5-1(a)(1) (10 CFR 90.121 - obtaining land)	Present ownership & control of land & all surface & subsurface mineral & water rights by DOE	Projected land-ownership conflict that cannot be successfully resolved by voluntary purchase-sell agreement, Federal condemnation proceedings, or agency-to-agency title transfer	none
	Meteorology 960.5-2-3	Located so expected meteorological conditions during operation & closure not lead to releases to unrestricted areas > specified in 960.5-1(a)(1)	Prevailing meteorological cond. so radioactive releases to atmosphere during operation & closure effectively dispersed, reducing likelihood of unacceptable exposure to any member in area	Prevailing meteorological cond. so radioactive emissions from repository operation or closure could preferentially transport to areas w/ higher pop. densities than average for the region; History of extreme weather phenomena significantly affecting re-ops. during operation & close	none
	Offsite installations and operations 960.5-2-4	Located so projected effects of nearby industrial, transportation, & military installation & operation will not affect repository from siting-decommissioning or when considered together, emissions operations & closure not likely to be > req. of 960.5-1(a)(1)	Absence of contributing releases from other nuclear installation & operations considered under req. of 40 CFR 161, subpart A	Presence of nearby potentially hazardous installations or operations adversely affecting reops. operation & closure; Other nuclear operations present w/ releases near max value permitted by 40 CFR 160-161	Disqualified if atomic energy defense activities in proximity to site expected to conflict w/ reops. from siting-decommission.
Environmental, Socioeconomics, & Transportation	Environmental quality 960.5-2-5	Quality of the environment in the affected area during this and future generations is adequately protected from siting through decommissioning; projected environmental impacts can be mitigated to an acceptable deg. taking into account programmatic, technical, social, economic, & environmental factors	Projected ability to meet, w/in time constraints, all Federal, State, & local procedural & substantive environmental factors; and the release requirements of 960.5-1(a)(2) can be met	Projected conflict w/ Federal, State, or local environmental req.; Projected adverse environmental impacts on State or regionally protected area; or a component to National Park, Wildlife, or Wilderness Protect. System; or a Native American resource; or proximity to any the above	Disqualified if quality of environment in affected area could not be adequately protected or unable to comply with favorable or overcome potentially adverse conditions
	Socioeconomic impact 960.5-2-6	Located so any signif. adverse social &/or economic impacts induced in community & surrounding regions can be offset by reasonable mitigation/compensation; the requirements of 960.5-1(a)(2) can be met	Ability to absorb project-related pop. changes w/o significantly impacts on housing supply & demand; Availability of adequate labor force in affected area; Projected net increases in employment & business sales, improved community services, & increased government revenues; no disruption of primary sectors	Significant impacts on community services, housing supply and demand, and finances of State & local agencies; Lack adequate labor force; Need for repository related purchase/acquisition of water rights, if such rights adversely impact present/future development; potential for major disruptions of primary sectors	Disqualified if repository would significantly degrade or reduce the quality of water from major water sources, or from offsite supplies for human consumption/crop irrigation
	Transportation 960.5-2-7	Located so the access routes from existing local highways & railroads to site will not conflict w/ the previously designated use of any resource; can design & construct using avail. technology; not required transportation components to meet performance standards more stringent than DOT or NRC regulations	Avail. & proximity of access routes from local existing rail & highways that provide access to regional highways & rails that are adequate to serve reops.; Regional railroad w/ min 8 interchange points; Total risk for transportation < than comparable siting operations; Availability of waste carriers capable & willing	Access routes to existing local highways and railroads that are expensive to construct relative to siting options; Terrain- steep grades, sharp switchbacks, lake, river, landslides, or potential hazard to incoming waste ship; Existing highway/rail requiring sig. reconstruction/upgrade; any cond. causing cost/impact/or risk	none
	Surface Characteristics 960.5-2-8	Considering surface characteristics & cond. of site and surrounding area, including surface-water & terrain, req. of 960.5-1(a)(3) met	Generally flat, well-drained terrain	Surface characteristics that could lead to flooding the surf. or underground facilities	none
Base & Cell of Siting, Construction, Operation, & Closure	Rock Characteristics 960.5-2-9	Located so the thickness and lateral extent & characteristic and composition of host rock suitable for underground facility; Repository construct., operation, & closure not cause undue hazard to personnel; must meet req. of 960.5-1(a)(3)	Host sufficiently thick & laterally extensive to allow significant flexibility in depth selection & configuration, and characteristics that require minimal/no artificial support for underground opening to ensure safe repository construction, operation, & closure	Unsuitable host rock, but too thin or too laterally restricted; In situ characteristics & cond. that could require engineer measures beyond avail. technology; Geomechan. prop. requiring extens. maintenance; Potential for phys. chem., or radioactive-induced phenomena leading to safety hazard; Stratigraphic problems	Disqualified if rock characteristics are such that activities assoc. w/ repository construction, operation, or closure are predicted to cause significant risk to safety to personnel
	Hydrology 960.5-2-10	Located such that geohydrologic setting will be compatible with repository activities; not hinder intended functions of the shaft liners & seals; meet requirement of 960.5-1(a)(3)	Absence of aquifers between between host rock & land surf.; Absence of surface-water sys. that could potentially cause flooding; Availability of the water required for repository construction, operation, or closure	Ground-water conditions that could require complex engineering measures that are beyond reasonably available technology for repository construction, operation, and closure	Disqualified if, based on expected ground water conditions, it is likely that engineering beyond available technology required for exploratory-shaft or reposit. construction, operation, or closure
	Tectonics 960.5-2-11	Located in geologic setting in which projected effects of expected tectonic phenomena or igneous activity on repository construction, operation, & closure will meet the req. in 960.5-1(a)(3)	The nature and rates of faulting, if any, w/in geologic setting are such that the magnitude & intensity of associated seismicity are significantly < those generally allowable for construction & operation of nuclear facilities	Evidence of active faulting w/in geologic siting; Historical earthquakes or past man-induced seismicity that could produce ground motion at site in excess of reasonable design limits; Evidence that magnitude of earthquakes at the site during construct., operation, and closure will be > predicted by past act.	Disqualified if, based on nature & rates of fault or other ground motion, it is likely that engineering measures beyond available technology will be required

NOTE: Additional information in all of these areas located in Appendix IV.

40 CFR 191 Subpart B Environmental Standards for the Uranium Fuel Cycle Compliance Structure

40CFR191.000
Rev. 12-18-81

40 CFR 264 Subpart X Permit for Misc. Unit Compliance Structure

40 CFR 264 Subpart X

40 CFR 268.6 Land Disposal Restriction Compliance Structure

40CFR-268.6
for TUSUS

Considerations,
Information
Needs &
Activities

Governing
Regulation

Compliance
Approach

Compliance
Support

10 CFR 20 Standards for Protection Against Radiation

10CFR20.600
rev. 10/20/98

DOE Order 5820.2A - Radioactive Waste Management: Chapter I - High Level Waste; Section 3d - Disposal Requirements

DO58202A.GCD
rev 11/21/93

Governing Order

Topics

Information

ACRONYMS

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
CFR	Code of Federal Regulations
COC	Certificate of Compliance
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
HLW	High-level Waste
INEL	Idaho National Engineering Laboratory
MGDS	Mined Geologic Disposal System
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
PA	Performance Assessment
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
SAR	Safety Analysis Report
SNF	Spent Nuclear Fuel
TRU	Transuranic Waste

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REFERENCES

- DOE/ID-10405, Idaho National Engineering Laboratory Installation Roadmap Document, DRAFT, May 1993.
- ORNL/M-1717, Hazardous Materials Transportation Act, Revision 5, October 15, 1991, Oak Ridge National Laboratory.
- ORNL/M-1900, Atomic Energy Act and Related Legislation, Revision 6, September 1, 1992, Oak Ridge National Laboratory.
- SAND86-0121, Assessing Compliance With the EPA High-Level Waste Standard: An Overview, October 1986, Sandia National Laboratories.
- Training Seminar Manual, Environmental Regulations Overview, July 1992, WINCO Environmental Training Personnel.

APPENDIX A

This Appendix provides potentially supplemental information for ensuring compliance with the requirements summarized in this document. It contains two letters reporting the results of an investigation of criticality issues related to the direct disposal of fuel in a geologic repository conducted by R.L. Nebeker, of WINCO.

Attachments to the letters outline and summarize various NRC Regulatory guides and ANSI standards. These summaries provide additional information relating to criticality safety. Attachment 1 of Neb-03-91 and Attachment 3 of Neb-04-91 summarize the content of various Regulatory Guides, ANSI Standards, and Regulations; Attachment 2 of Neb-03-91 gives impacts, proposed resolutions, and long term implications of specific requirements set forth in 10 CFR 60, 40 CFR 191, and DOE Order 5480.5. These two regulations, 10 CFR 60 and 40 CFR 191, have been summarized in more detail in the MGDS section. Attachment 2 of Neb-04-91 does the same for various Regulatory guides; however, no flow diagram summaries for Regulatory guides are prepared in this document.

Other potentially applicable federal directives are contained in DOE Order 5480.4 - Environmental Protection, Safety, and Health Protection Standards. This Order categorically lists directives and reported procedures to be followed when conducting activities outlined in the various sections of this document. For example, under the Radioactive Material Packaging and Transportation Safety section (Page 12 of Attachment 3 of this Order), references such as *ORNL-NSIC-68, 1970, "Cask Designers Guide"* (ORNL) and *NRC Guide 7.4, "Leakage Tests for Shipment of Radioactive Materials"* (NRC) are listed.

No detailed investigation into the applicability of the references in this appendix has been conducted. However, it is believed that some of these referrals will contain useful information as new operations and activities at the INEL relative to the SF&WMTDP are developed.

Neb-03-91

From R. L. Nebeker

Phone 6-3578

Date October 22, 1991

Subject: Criticality Implications of Direct Disposal of Fuel

To N. A. Chipman, Fellow Engineer
New Business and Special Studies

cc: G. B. Frandsen
R. N. Henry
G. W. Hogg

V. C. Maio
B. R. Wheeler
R. L. Nebeker - 2

As you requested, I have reviewed various regulations and standards concerning criticality issues related to the direct disposal of fuel in a geological repository. A list of these regulations and their highlights are provided in Attachment 1.

In general, the regulations do not specifically apply to repository disposition, but to other aspects of fuel handling. However, regulations for repository disposition of fuel would be expected to contain the general restrictions shown in these regulations.

Attachment 2 summarizes the requirements of these regulations as well as other regulations concerning fuel disposition in a repository (mainly concerning the stability of the repository package) which indirectly impact criticality control.

For direct disposal of fuel, two time periods are of concern: "short," corresponding roughly to the length of time a canister must retain its integrity and "long," when container integrity cannot be guaranteed. The need for criticality control in a repository is discussed in 10CFR60.131(7), but nothing is said regarding the time periods for which the criticality control requirements must be met. The NRC staff has identified this as an "uncertainty", and the issue is presently being studied by NRC personnel.

Rick Weller of the High-Level Waste Program for the NRC was contacted regarding the time periods for which criticality control requirements in 10CFR60 must be met. He indicated that a staff position is being developed and an NRC Guidance Document on the subject will be issued in the next several months. Most likely, the guidance will require that criticality control be considered in both the preclosure and post closure periods. Analyses must be completed to evaluate criticality impacts in meeting performance criteria for the duration of the period of interest, which is assumed to be 10,000 years, based on EPA requirements in 40CFR191.

N. A. Chipman
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October 22, 1991

While it appears that criticality could be controlled with adequate design in the "short" time period, it also appears that there is absolutely no way to guarantee that a criticality will not occur over the time the fissile material in the spent fuel would remain in the repository.

Obviously, disposing of the fuel directly instead of removing the fissile material (uranium and plutonium) increases the care and attention that must be given to the waste package because of criticality concerns. Some of the additional concerns are:

1. Each "package" must be assured to be critically safe. For HEU fuel, this could involve additional fuel disassembly steps prior to packaging or adding nuclear poisons to the package.
2. The spacing within the repository would have to be analyzed to determine that the array of spent fuel is subcritical for all possibilities. This spacing may be more or less restrictive than spacing for heat removal.
3. The intrusion of water into the repository over long time periods would adversely affect the fuel reactivity and would have to be considered in all criticality analyses.
4. Over long periods, movements through faulting or other earth shifting methods might change the geometry of the fuel array or damage the package and reduce its lifetime, making it more reactive.
5. Over long periods, nuclear poisons could conceivably be selectively leached from the fuel package, resulting in higher reactivities. The decay of fission product poisons in the fuel would also increase the reactivity in the fuel, even in the "short" term.
6. Selective movement of uranium is conceivable over the long term if the uranium is dissolved and reprecipitated. This also might increase the reactivity within the repository.
7. Typically, inspections are required to verify that any nuclear poisons used for criticality control remain in place and are not removed. Inspection to assure canister arrays and the integrity of the canister may also be an issue. Inspection after placement in a repository might be impossible or would require extensive fuel handling.
8. Intrusion to prevent diversion of HEU is not addressed in existing regulations but would be a logical safeguard issue that would be expected to arise during the public review process. Unlike commercial fuel, HEU fuel would require less refining to prevent an SNM threat.

N. A. Chipman
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October 22, 1991

In summary, it would appear that confinement of fission products via engineered barriers (canister and repository) is feasible, but assurance of criticality safety cannot be demonstrated for geologic time.

In addition to these criticality issues there are other issues concerning fuel configuration that indirectly affect criticality control that must be resolved if fuel is disposed of directly. Among these are:

1. Elimination of combustibles/reactives will be required of fuels containing graphite or carbides before they can meet today's requirements. This could require extensive pretreatment prior to disposal.
2. Solidification of particulate matter would be required for any powdered fuel or fuel residue, again requiring a type of pretreatment.
3. Fuels would have to be characterized to demonstrate their ability to retain fission products and to assure regulators that material going to the repository is known and understood. Because of the many types of fuel (over 30 general types at the ICPP alone), this would require an extensive amount of time and money (probably over a billion dollars over many years).

It is doubtful that these issues can be analyzed in a manner that would convince the public that HEU type fuel or even commercial LEU fuel can be disposed of directly to a repository without generating a criticality safety risk. Whether or not the issues are really problems may be immaterial; if they are perceived as problems by the public, it will be impossible or difficult to get public acceptance. While it may be technically acceptable to say that the risk of a criticality deep underground in a geological repository is acceptable and can be analyzed based on data from the Oklo Natural Reactor, it is doubtful that the general public would accept such a risk. Furthermore, failure to remove the fissile material (the technology does exist) casts doubt on DOE's commitment to make nuclear safety their number one priority.

Obviously, this issue will have to be developed further over a period of time. If I can be of any further help, or supply further information, let me know.

R. L. Nebeker/RAA

R. L. Nebeker
Fellow Engineer

Attachments

/rg

Attachment 1

Summary of Guidance Documents Pertaining to Criticality and Fuel Storage

Document	Title	Summary of Contents
10CFR60	Disposal of High-Level Radioactive Wastes in Geologic Repositories	This regulation lists general provisions for disposal of HLW and describes license application requirements. It contains performance objectives and design criteria.
10CFR60.113	Performance of Particular Barriers After Permanent Closure	Requires HLW containment during fission product decay time. Requires gradual release of radionuclides from barrier system. Requires containment for 300-1000 years.
10CFR60.131	General Design Criteria for the Geologic Repository Operations Area	Requires radiation doses, levels and concentrations to be within established levels. Lists design criteria for repository. Requires steps to minimize possibility of a criticality.
10CFR60.135	Criteria for the Waste Package and Its Components	Requires package for HLW to be able to withstand environmental attacks. Lists criteria to be met by waste forms.
40CFR191	Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste	Lists standards for radiation doses received by public as a result of management and disposal activities. Discusses radioactive material releases as a result of disposal.
40CFR191.03	Standards	Gives dose limits to public for disposal activities.
40CFR191.13	Containment Requirements	Provides standards for design of containment and lists release likelihoods to be obtained.

Document	Title	Summary of Contents
40CFR191.14	Assurance Requirements	Discusses institutional controls, monitoring, marking, barriers, mining, and waste removal.
40CFR191 Appendix A	Table for Subpart 13	Lists cumulative releases to the accessible environment for 10,000 years after disposal for specific nuclides and groups.
DOE Order 5480.5	Safety of Nuclear Facilities	Describes basic requirements for DOE's environment, safety and health program. Basic elements of nuclear criticality safety are presented along with Nuclear critical ty safety control parameters.
NRC Regulatory Guide 1.13	Spent Fuel Storage Facility Design Basis	Presents methods for assuring that fuel storage and handling system are designed for adequate safety under normal and postulated accident conditions.
NRC Regulatory Guide 3.4	Nuclear Criticality Safety in Operations with Fissionable Materials at Fuels and Materials Facilities	Describes procedures for preventing accidental criticality in operations with fissionable materials at fuel cycle facilities other than reactors. Refers to ANSI/ANS-8.1-1983.
NRC Regulatory Guide 3.33	Assumptions used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Fuel Reprocessing Plant	Provides methods and equations for determining the impacts of a criticality on the public health and safety. Describes how to estimate the consequences of an accidental criticality as it applies to a fuel reprocessing plant.
NRC Regulatory Guide 3.34	Assumptions used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Uranium Fuel Fabrication Plant	Provides methods for determining the impacts of a criticality on the public health and safety as it applies to a uranium fuel fabrication plant.

Document	Title	Summary of Contents
NRC Regulatory Guide 3.43	Nuclear Criticality Safety in the Storage of Fissile Materials	Provides guidance for procedures to avoid accidental criticality during storage of fissile materials. Refers to ANSI N16.5-1975.
NRC Regulatory Guide 3.57	Administrative Practices for Nuclear Criticality Safety at Fuels and Materials Facilities	Provides guidance for safety procedures which are part of a nuclear safety program. Refers to ANSI/ANS 8.19-1984.
NRC Regulatory Guide 3.58	Critical Safety for Handling, Storing, and Transporting LWR Fuel at Fuels and Materials Facilities	Provides guidance for preventing criticality accidents during handling, storage, and transporting of LWR fuel outside of nuclear reactors. Refers to ANSI/ANS-8.17-1984.
NRC Regulatory Guide 3.60	Design of an Independent Spent Fuel Storage Installation (Dry Storage)	This document provide guidance for use in the design of a dry storage independent spent fuel storage installation. It refers to ANSI/ANS-57.9-1984.
NRC Regulatory Guide 8.12	Criticality Accident Alarm Systems	This guide describes a system for meeting requirements for a criticality accident alarm system. it refers to ANSI/ANS-8.3-1986.
ANSI/ANS-8.1-1983	American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors	This standard provides guidance for the prevention of criticality accidents in the handling, storing, processing, and transporting of fissionable material.
ANSI/ANS-8.3-1986	Criticality Accident Alarm System	This standard provides guidance for the establishment and maintenance of an alarm system to initiate personnel evacuation in the event of inadvertent criticality.

Document	Title	Summary of Contents
ANS-8.7/ANSI N16.5-1975	Guide for Nuclear Criticality Safety in the Storage of Fissile Materials	This guide provides orientation and direction to nuclear safety practices.
ANSI/ANS-8.17-1984	American National Standard, Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors	This standard provides basic requirements that address the criticality safety aspects of a facility or operation that can be referenced or used in conjunction with other safety standards or regulations.
ANSI/ANS 8.19-1984	American National Standard - Administrative Practices for Nuclear Criticality Safety	This standard presents a codification of certain common safety elements related to criticality safety.
ANSI/ANS-5.79-1984	American National Standard - Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)	This standard provides design criteria for an Independent Spent Fuel Storage Installation for LWR spent fuel which incorporates one or more of the dry storage concepts.

Attachment 2

Criticality and Other Requirements for Spent Fuel Disposal

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Containment until fission products decay (300-1000 years)	10CFR60.113	Extensive fuel characterization required for many different fuel types.	Repository to be constructed to provide containment: characterize fuel.	Probably attainable for required time.
Slow release of radionuclides (1/100,000 per year)	10CFR60.113	Must demonstrate for fuel inventory as well as criticality fission products. Must show slow release of gaseous fission products from criticality.	Characterize fuel, perform analyses.	Probably obtainable for many fuels.
Maintain air concentrations below 10CFR20 limits	10CFR60.131	Retention of fission products required.	Canister should be adequate if it remains intact.	Release of gaseous fission products from criticality must be analyzed.
Double contingency to prevent criticality	10CFR60.131(7) DOE 5480.5, ANSI/ANS-8.1- 1983	May require extensive spacing, use of poison, or other requirements.	Various solutions possible for short term.	Unable to demonstrate compliance in long term.
Keff to have a 5% margin	10CFR60.131(7)	May limit spacing/ packaging of fuel.	Spacing, poisons, disassembly or other methods.	Unable to demonstrate compliance in long term.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
In-situ chemical reactions do not compromise package	10CFR60.135	Must show that poisons remain in place; that uranium is not concentrated by chemical action.	Canister will provide protection during "short" term.	Long term compliance will be difficult to demonstrate.
In-situ physical properties do not compromise package	10CFR60.135	Physical movement of fuel leading to criticality must be prevented.	Repository geology will demonstrate short-term compliance.	Long-term stability will be difficult to demonstrate.
In-situ nuclear properties do not compromise package	10CFR60.135	High radiation, criticality must not impact package.	Short term compliance by spacing, poisons, etc.	Long-term demonstration of lack of damage from criticality difficult to demonstrate.
Consider solubility	10CFR60.135	Poisons could be lost or uranium concentrated by solubility.	Container will provide protection in short term.	Cannot demonstrate compliance in long term.
Consider oxidation/reduction reactions	10CFR60.135	Poisons could be lost or uranium concentrated by Redox reactions.	Containers will provide protection in short term	Cannot demonstrate compliance in long term.
Consider corrosion	10CFR60.135	Poisons could be lost or uranium concentrated by corrosion of container and fuel.	Containers will provide protection in short term.	Cannot demonstrate compliance in long term.
Consider hydriding	10CFR60.135	May result in more reactivity of fuel, excessive corrosion.	Containers will provide protection in short term.	Cannot demonstrate compliance in long term.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Consider gas generation	10CFR60.135	Criticality, reactive fuels can create gas.	Pretreat reactive fuels, fuels will be protected against criticality in short term.	Long term compliance difficult to demonstrate.
Consider thermal effects/loads	10CFR60.135	Overheating will increase fission product release migration.	Spacing, fuel disassembly can limit thermal effects.	Criteria can probably be met.
Consider mechanical strength	10CFR60.135	Mechanical failure could position fuel in more reactivity geometry.	Containers will be mechanically stable in short time.	Cannot demonstrate compliance in long term.
Consider mechanical stress	10CFR60.135	Mechanical stress may deform fuel into more reactive configuration.	Canister will provide protection in short term.	Long term compliance may be difficult to demonstrate.
Consider radiolysis	10CFR60.135	May result in gas generation.	Short term compliance built into design.	Evaluate effect of long-term radiation exposure.
Consider radiation damage	10CFR60.135	Could result in higher radionuclide release.	Package will be designed for calculated radiation dose.	Must show that fuel is not significantly different from waste in terms of radiological source form. Alpha activity will last for long term.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Consider radionuclide retardation	10CFR60.135	Fuel must be as good as waste form for fission product acceleration.	Characterize fuel to demonstrate ability to retain radionuclides.	Characterization will be expensive, time consuming; must retain radionuclides from a criticality.
Consider leaching	10CFR60.135	Leaching may remove poison or concentrate uranium. Water will increase fuel reactivity. Fuel must be as resistant as waste form.	Short term compliance will be provided by package.	Long-term compliance will be difficult to demonstrate.
Consider fire and explosion hazards	10CFR60.135	Some fuels may be combustible/reactive.	Pretreat combustible/reactive fuels prior to disposal.	Pretreatment will require extensive facilities.
Consider synergistic interaction	10CFR60.135	Criticality control requires added dimension of requirements.	Adequate plans, calculations and methods can be prepared.	Increased time and effort will be required.
No pyrophoric materials	10CFR60.135 DOE 5480.5	Pyrophoric fuel would have to be pretreated.	Pretreat required fuel.	Pretreatment facility would be costly.

Assumption/Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
No chemically reactive materials	10CFR60.135	Combined fuels would require pretreatment.	Pretreat fuel as necessary.	Pretreatment facility would be costly.
Consolidate Particulates	10CFR60.135	Powdered fuel or residue would have to be consolidated.	Pretreat fuel as necessary.	Pretreatment facility would be costly.
Reduce to noncombustible form	10CFR60.135	Certain fuels would require pretreatment.	Pretreat fuels as necessary.	Pretreatment would be costly.
Maintain dose to public below 25 mr whole body	40CFR191.03	None for short term.	Provide adequate packaging/ shielding.	Difficult to demonstrate for long term.
Releases to have less than 1/1000 chance of exceeding release limits	40CFR191.13	Fuel must be as good a form as waste.	Characterize fuel; preprocess if required	Long-term compliance difficult to prove.
Monitor disposal systems	40CFR191.13	Install monitoring system.	Monitoring practical in short term.	Cannot verify compliance in long term.
Do not preclude removal of waste	40CFR191.14	Design for removal.	Repository/package design in short term.	Cannot verify in long term.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Consider all potential criticality hazards	DOE 5480.5	Criticality prevention adds additional requirements and care.	Repository design, fuel size.	Cannot verify in long term.
Ensure process is subcritical under both normal and abnormal operating/credible conditions	DOE 5480.5 ANSI/ANS 8.1-1983 ANSI/ANS 8.19-1984	Extra care required in handling/storage.	Spacing, poisoning, etc. may be required in package.	Long term compliance cannot be guaranteed.
Avoid entry of water into storage area	DOE 5480.5	Fuel reactivity will be increased in wet environment	Repository construction will provide compliance for short term.	Difficult to demonstrate for long term.
Poisons can be used if available data assures presence and reliability	DOE 5480.5	Loss of poison will result in increased fuel reactivity.	Container will provide assurance in short term but cannot inspect to assure presence.	Long-term presence of poison cannot be demonstrated. Cannot inspect to guarantee presence.
Assure prescribed extent of moderation remains unchanged	DOE 5480.5	Increased moderation will increase fuel reactivity.	Container/repository design will provide assurance in short term.	Long term changes are likely but cannot be specified.
Reflection based on result of credible accident	DOE 5480.5	Increased reflection will increase fuel reactivity.	Repository design will provide assurance in short term.	Long-term geological events may change dimensions/spacing.

Assumption/Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Maintain all dimensions and nuclear properties relied on for geometry control	DOE 5480.5	Change in geometry may increase fuel reactivity.	Original spacing can be relied on for short term.	Long-term geological events may change dimensions/spacing.
Periodic inspections, insitu tests, and preventive maintenance needed for criticality control	DOE 5480.5	Inspection cannot easily be made after installation in repository.	None	Inspection, etc. impossible in long term.
Control spacing, mass, density and geometry under normal and abnormal conditions	ANSI/ANS-8.19 1984	Control is lost after placement in repository.	None	Physical changes to repository, fuels, etc. possible in long term.
Spent fuel storage facility to meet Category I seismic requirements	RG 1.13	Seismic events could rearrange fuel, resulting in criticality.	Repository design will provide protection in the short term.	Demonstration of long term compliance is difficult.
Obviate concern for criticality in event of fire, flood, earthquake, or other natural calamities.	ANS-8.7/ANSI N16.5-1975	Natural phenomena may result in increased fuel reactivity.	Repository design should meet standard in short term.	Demonstration of long term compliance is difficult.

Neb-04-91

From R. L. Nebeker
Phone 6-3578/MS 5219
Date October 29, 1991
Subject Review of Task Team 12 Criticality Information

To N. A. Chipman, Fellow Engineer
New Business and Special Studies

cc: G. B. Frandsen
R. N. Henry
G. W. Hogg
V. C. Maio
B. R. Wheeler
R. L. Nebeker - 2

Reference: R. L. Nebeker, Letter Neb-03-91, to N. A. Chipman, "Criticality Implications of Direct Disposal of Fuel," dated October 22, 1991.

At your request, the information submitted by Task Team 12 concerning criticality implications of direct fuel disposal was reviewed. In that submittal, various regulations were referenced which apply to criticality prevention. All of these references except two were described earlier in the reference to this letter. Task Team 12 referred to two NRC Regulatory Guides not included in Letter Neb-03-91: Reg Guide 3.41 and Reg Guide 3.48.

NRC Regulatory Guide 3.41 was withdrawn by the NRC on March 20, 1986 and has been replaced with NRC Regulatory Guide 3.4 (see Attachment 1). Consequently, it was not included in Neb-03-91. NRC Regulatory Guide 3.48 describes the format and contents for safety analysis reports (SARs) for fuel storage. It lists certain information to be included in the SAR which indirectly impacts criticality prevention during fuel storage. For completeness, these requirements, and implications of meeting the requirements, are shown in Attachment 2. A summary of both regulatory guides is shown in Attachment 3 in the same format as originally shown for other regulations in Neb-03-91.

If further information is needed, please let me know.

A handwritten signature in dark ink, appearing to read "R. L. Nebeker", followed by a horizontal line.

R. L. Nebeker
Fellow Engineer

/tl

Attachments

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 20, 1986

REGULATORY GUIDE DISTRIBUTION LIST (DIVISION 3)

SUBJECT: ISSUANCE OF REVISION 2 TO REGULATORY GUIDE 3.4 AND
WITHDRAWAL OF REGULATORY GUIDE 3.41

With the issuance of Revision 2 to Regulatory Guide 3.4, "Nuclear Criticality Safety in Operations with Fissionable Materials at Fuels and Materials Facilities," the NRC staff is withdrawing Regulatory Guide 3.41 "Validation of Calculational Methods for Nuclear Criticality Safety."

Revision 2 to Regulatory Guide 3.4 endorses ANSI/ANS-8.1-1983, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," which is a consolidation of ANSI N16.1-1975/ANS-8.1 (endorsed by Revision 1 of Regulatory Guide 3.4) and ANSI N16.9-1975/ANS-8.11 (endorsed by Regulatory Guide 3.41). Regulatory Guide 3.41 is therefore obsolete. However, withdrawal of Regulatory Guide 3.41 is in no way intended to alter any prior or existing licensing commitments based on its use.

Regulatory guides may be withdrawn when they are superseded by the Commission's regulations, when equivalent recommendations have been incorporated in applicable approved codes and standards, or when changes in methods and techniques or in the need for specific guidance have made them obsolete.

Robert B. Minoque

Robert B. Minoque, Director
Office of Nuclear Regulatory Research

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Attachment 2

Criticality and Other Requirements for Spent Fuel Disposal

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Evaluate fuel storage sites for: vulnerability to accidents from natural phenomena, radiation shielding, confinement, and control of radioactive materials, etc.	Reg Guide 3.48	Significant analyses required prior to fuel placement.	These items will be analyzed as part of repository preparation.	Long-term analyses require making assumptions without fully understanding future events.
SAR should discuss flood history, flood design considerations, local intense precipitation losses, run off model, probable maximum flood flow, water level determinations, ice flooding, dam failures, and other potential flooding mechanisms.	Reg Guide 3.48	Significant analyses of past and predicted future events required. Flooding could adversely affect reactivity of fuel.	These items, based on past events, will be analyzed in detail for repository.	Long-term analyses will require making assumptions without fully understanding future events.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Describe earthquake history, identify and describe capable faults, determine maximum earthquake, describe surface faulting, geologic features, properties of underlying materials, ground water conditions, etc.	Reg Guide 3.48	Significant analyses of past and predicted future events required. Geologic change could adversely affect reactivity of fuel.	These items, based on past events, will be analyzed in detail for geologic repository.	Long-term analyses will require making assumptions without fully understanding future events.
Provide a detailed description of material to be stored, including physical, thermal, and radiological characteristics. Include specific power, burnup, decay time, heat generation rates, etc.	Reg Guide 3.48	Significant characterization required.	Detailed characterization work will be completed prior to placement of fuel in repository.	Information for some fuels will be lacking even in short term.

Assumption/ Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Provide information concerning tornado missiles, floods, flood elevations, flood force, flood protection, seismic design, snow and ice loadings, etc.	Reg Guide 3.48	Significant analyses required. Flooding or fuel movement could adversely affect fuel reactivity.	Analyses will be completed at time of repository construction.	Long-term analyses will require making assumptions without fully understanding future events.
Describe control methods for prevention of criticality and error contingency criteria. Describe the design features, procedures, and special techniques to preclude criticality.	Reg Guide 3.48	Significant analyses required.	Analyses will be completed at time of repository construction.	Certain control methods cannot be guaranteed to be viable for long terms.
Describe systems for providing safety under normal and abnormal conditions.	Reg Guide 3.48	Extensive descriptions will be required.	Description will be required when repository is built.	Facility and system will not remain in original configuration for long periods.

Assumption/Requirements	Reference	Impact	Proposed Resolution	Comments/Long Term Implications
Analyze potential accidents, including causes, detection, effects and consequences, corrective actions, etc.	Reg Guide 3.48	Extensive analyses will be required.	Analyses will be part of geologic repository SAR.	Long-term analyses must be based on inadequate information.
Conduct of Operation items to be described.	Reg Guide 3.48	Descriptions will be prepared.	These conditions will be followed during storage of fuel.	These conditions cannot be guaranteed for long time periods.

Attachment 3

Summary of Guidance Documents Pertaining to Criticality and Fuel Storage

Document	Title	Summary of Contents
NRC Regulatory Guide 3.41	Validation of calculational methods for nuclear criticality safety.	Withdrawn 3/20/86 and replaced by Regulatory Guide 3.4.
NRC Regulatory Guide 3.48.	Standard format and content for the Safety Analysis Report for an independent spent fuel storage installation or monitored retrievable storage installation (dry storage).	This guide presents a standard format that is acceptable to the NRC staff for the SAR required for a license application to store spent fuel in an independent spent fuel storage installation or to store spent fuel and high-level radioactive waste in a monitored retrievable storage installation.

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