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Facts and Issues of Direct Disposal of Spent Fuel (U)

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Savannah River Site
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
SRS
SAVANNAH RIVER SITE

Prepared for the U. S. Department of Energy under Contract No. DE-AC09-89SR18035.

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Facts and Issues of Direct Disposal of Spent Fuel

Introduction

This report reviews those facts and issues that affect the direct disposal of spent reactor fuels. It is intended as a resource document for those impacted by the current Department of Energy (DOE) guidance that calls for the cessation of fuel reprocessing. It is not intended as a study of the specific impacts (schedules and costs) to the Savannah River Site (SRS) alone. Commercial fuels, other low enriched fuels, highly enriched defense-production, research, and naval reactor fuels are included in this survey, except as prevented by rules on classification.

In the past, all of the DOE-owned spent fuels were to be reprocessed to separate the uranium and plutonium isotopes from the fission products. However, all but two of the DOE reprocessing facilities have been shut down. Further reprocessing of spent fuel can be performed only in the SRS F- and H-Canyon facilities, but, according to the present guidance from DOE, these facilities are scheduled to be shut down in the 1994-1997 time frame. These actions will leave a large legacy of spent fuels for which direct disposition in a geologic repository will be the only means of disposal.

The Discussion of this report begins with a short review of the policy decisions (Section 1) that have been made in the past regarding the disposition of reactor fuels and wastes. This discussion leads directly into a review of the Yucca Mountain program for construction of the nation's first geologic waste repository (Section 2). Recent international nuclear disarmament treaties have called into question many policies concerning nuclear weapons production. In particular, reprocessing of irradiated enriched fuels has been halted, leaving direct disposal as the only remaining option for spent fuel disposal (Section 3). Section 4 highlights the many, often conflicting, views concerning the suitability of geologic repositories for direct disposal of enriched fuels and the potentially volatile nature of this continuing debate.

Section 5 reviews the regulations and orders that have been issued by EPA, NRC, and DOE for geologic repositories. Section 6 presents a summary of the known commercial and DOE-owned stocks of unclassified irradiated fuel. Section 7 presents a review of criticality, the principal unresolved issue facing direct disposition of irradiated fuel in a geologic repository. Other unresolved issues, Safeguards and Classification, are discussed in Sections 8 and 9, respectively. An Appendix includes several reference documents to make this exposition as self-contained a resource document as possible.

Summary

The existing inventories of spent reactor fuel already owned and stored by the Department of Energy are extensive. Until recently, it was assumed that all or most of the DOE fuels would be processed to recover the fissionable uranium and/or plutonium, and the remaining high-level waste would be vitrified for burial in a geologic repository. The first high-level waste repository, planned for Yucca Mountain in Nevada, would hold canned commercial spent fuel and canisters of vitrified defense high-level waste. In 1998, the Department of Energy is supposed to take legal title to the commercial nuclear fuel that is currently stored in spent fuel pools at the nuclear utility sites around the nation. The totals of all the DOE-owned spent fuel and the soon-to-be-owned commercial spent fuel are listed in Table S.1 (excluding naval fuel).

Recently, DOE policy was changed to cease reprocessing of defense and research fuels. Reprocessing facilities at Hanford and Idaho have already been shut down. The remaining F- and H-Canyon facilities at SRS are scheduled for shutdown in the 1994-1997 time frame, and only some of the fuels currently stored at SRS are likely to be processed. Thus, most of the non-commercial fuels listed on Table S.1 will have to be prepared for direct disposition in a geologic repository.

A large fraction of the research and defense-related spent fuels were fabricated from highly enriched uranium (HEU), and are very unlikely to be entombed in the Yucca Mountain repository. These HEU fuels, as well as a significant fraction of the commercial fuels, will have to be stored until completion of a second geologic repository because:

- HEU spent fuel is not specifically covered by the Nuclear Waste Policy Act of 1982 or its 1987 revision. An amendment by Congress would probably be necessary for HEU spent fuels to be placed in the first geologic repository (Yucca Mountain).

Table S-1

United States Spent Fuel Inventories

Type of Spent Fuel	Total Heavy Metal (U + Pu + Th) Metric Tons
Hanford	
N-Reactor LEU	2094
Miscellaneous	<6
Idaho (excluding Naval Fuels)	
Special Fuels	83
Three Mile Island (LEU)	82
SRS (excluding production fuels)*	
RBOF (HEU + LEU)	19
Other DOE Sites	<2
Commercial (LEU)	19,000 in 1989
"no new orders"	77,000 by 2020
"25% of total US"	97,000 by 2020

* The production fuels at SRS have been excluded because they are scheduled for reprocessing.

- All space at Yucca Mountain is already reserved for commercial spent fuel and high-level waste.

- Repository space for HEU spent fuels would be in a second repository, which, by law, cannot be requested until ~ 2007-2010, and could not accept spent fuel until ~ 2030-2040.

Qualification of commercial spent fuels for direct disposal is already known to be a difficult task: the qualification of the HEU spent fuels will be even more difficult. All of these fuels will present criticality problems at the repository. Criticality is not the only issue affecting direct disposal (the others are Safeguards and Classification), but it is by far the most important and difficult to resolve. A possible outcome of deliberations concerning highly enriched spent fuels is that their disposal could be banned from geologic repositories.

Doubts about the choice of direct disposition are reinforced when the costs and waste volumes from direct disposition are compared with the costs and waste volumes from continued reprocessing. Three studies of the costs of direct disposal versus reprocessing that differ considerably in their assumptions have been reviewed. The principal differences have to do with the ability to use existing reprocessing facilities and the value that is placed on the unburned HEU that is recovered by reprocessing. Table S-2 reviews the study assumptions. Table S-3 reviews the cost estimates derived from the studies. These studies support the conclusion that **reprocessing is cheaper than direct disposal if the reprocessing facilities already exist and if all lifetime costs are considered.**

The SRS-RBOF study showed that reprocessing is much less costly than direct disposal, if you can use existing facilities with little modification. The ICPP study recommended extensive modifications that increased the costs of reprocessing to rough equality with the costs of direct disposal at the Idaho site. The SRS-NPR study called for the construction of a new reprocessing facility to separate the bulk of the fission products from the uranium. This caused the costs of this "partitioning" step to exceed the cost of direct disposal.

The waste volumes (in terms of similar volume canisters) of spent fuel and high-level wastes are compared in Table S-4. The SRS-RBOF study predicted much less HLW being generated than spent fuel. The ICPP study also predicted much less HLW when the proposed aqueous-pyrometallurgic reprocessing technology is used. The SRS-NPR study predicted roughly similar volumes of spent fuel and high-level wastes.

In view of the difficult technical and institutional issues associated with the eventual disposal of DOE spent fuels, either directly or via reprocessing, a comprehensive DOE-wide study of all dispositions options, which would meet the National Environmental Policy Act requirements, should be conducted before any decision that would eliminate DOE's spent fuel reprocessing capabilities.

Table S-2
Parameters of Three Studies of Direct Disposal vs. Reprocessing for Government-Owned Spent Fuels

Author	Fuel Type and Amount	Direct Disposal Method	Does Reprocessing Facility Exist?	Value and Fate of Recovered HEU
J.M. McKibben[7]	SRS-RBOF Special Fuels, All inventory	Mass Limited Canisters	Yes. (H-Canyon)	High Value, Save
R.N. Henry et al.[3]	ICPP Current Stockpiles and Future 40-Year Receipts	Unpoisoned Fuel Poisoned Fuel, Diluted Fuel	Yes. (ICPP) but several upgrades are proposed	High Value, Save
L.W. Patrick[8]	SRS NPR-HWR, Lifetime of Reactor	Unpoisoned Fuel, Poisoned Fuel, Diluted Fuel	No. New Canyon required for "Partitioning, single stage"	No Value, Bury

Table S-3
Estimated Costs of Direct Disposal vs. Reprocessing for Government-Owned Spend Fuels*

Author	Fuel Type and Amount	Disposal Method	Estimated Cost ($ Millions)
J.M. McKibben[7]	SRS-RBOF Special Fuels All Inventory (1.2 MTHM)	Direct Mass Limited ≤ 1 kg HEU/canister)	$ 1,190
		Reprocessing	$ 190
R. N. Henry et al.[3]	ICPP Current Stockpiles and Future 40-Year Receipts	Direct Unpoisoned (but limited to ~ 16 kg/ canister)	$18,365
		Poisoned (~22 kg/canister)	$17,879
		Diluted	$26,264
		Reprocessing (with upgrades)	$19,827
L.W. Patrick[8]	SRS NPR-HWR, Lifetime of Reactor (31% HWR, Option G, 2 batch)	Direct Unpoisoned	$ 1,929
		Poisoned	$ 1,284
		Diluted	$ 1,322
		Partitioning-single stage	$ 2,120

**Note that the quoted costs are for dealing with the different inventory amounts at each site or facility.*

Discussion

1. Background

1.1 Waste Disposal Policies

Historically, the United States has always subjected its defense-related spent nuclear fuels to chemical reprocessing. The principal reason was to recover the unburned HEU remaining in those fuels after irradiation. HEU was both scarce and expensive to produce in the gaseous diffusion plants. Moreover, the competing needs of the weapons programs for HEU were severe.

Reprocessing was also planned for commercial spent fuel from the beginning of the nuclear power industry. The use of large quantities of low-enriched uranium stocks not only placed a burden on the gaseous diffusion plants, but was also perceived as depleting the existing natural uranium stocks around the world. The West Valley site in New York state was one of the early sites to provide low-enriched spent fuel reprocessing.

Additional reprocessing sites for commercial spent fuels were also planned and built. The Allied General Nuclear Services (AGNS) plant was constructed and nearly finished in Barnwell, South Carolina, when the Carter Administration imposed a ban on reprocessing of commercial fuel. The technology of commercial fuel reprocessing was similar to that for weapons-grade plutonium-bearing targets. The concern was that non-weapons states might be encouraged to become weapons states, if the United States encouraged their reprocessing of commercial fuels.

The Reagan Administration reversed the Carter ban on commercial fuel reprocessing. However, to date, no new commercial reprocessing ventures have been undertaken, nor has the AGNS plant been finished. The principal reason is that natural uranium prices have fallen so low that reprocessing commercial fuel is no longer deemed cost-effective. HEU stocks, from which LEU stocks may be made, are now abundant because of the declining nuclear weapons stockpiles worldwide. The need for commercial fuel reprocessing may revive in the future, but for now, reprocessing of commercial fuel does not appear to be a viable enterprise in the United States.

In recognition of the above trends in the nuclear fuel industry, DOE issued an Environmental Impact Statement on reactor waste in 1980, followed by a formal Record of Decision that adopted geologic disposal as the method of disposal for both commercial spent fuels and for defense high-level wastes (including the West Valley waste).

1.2 The Nuclear Waste Policy Act of 1982

In response to DOE's Record of Decision recommending geologic disposal of reactor waste, and because of the furor raised in anti-nuclear and environmental circles over the supposedly unsolved problem of nuclear waste, Congress passed the Nuclear Waste Policy Act of 1982. DOE was directed to undertake site characterization studies to select one or more sites where geologic waste repositories could be constructed. The Act assigned the responsibility to manage spent commercial nuclear fuel and HLW to DOE, with the costs of those activities to be incurred by the owners/generators of the waste. Several site investigations were begun by DOE, the most prominent of which was Yucca Mountain on the border of the Nevada Test Site property. The act further stipulated that 70,000 MTHM would be disposed of in the first repository (8,000 MTHM of defense HLW and 62,000 MTHM of commercial spent fuel).

1.3 The Amended Nuclear Waste Policy Act of 1987

The Nuclear Waste Policy Act was amended in 1987 to eliminate all DOE site characterization studies except for those at Yucca Mountain. Congress also prohibited DOE from requesting a second repository (besides Yucca Mountain) for a least 20 years. Hence, no new site can be requested before 2007.

1.4 The Energy Policy Act of 1992

Among other actions, Section 803 of the Energy Policy Act of 1992 directs DOE to examine the adequacy of the current waste disposal program to manage additional volumes or categories of nuclear waste that may be generated by new nuclear power plants or by defense facilities in view of the current cessation of reprocessing. The report by the Office of Civilian Radioactive Waste Management is scheduled for publication in October 1993.

Table S-4
Estimated Waste Volume From Direct Disposal vs. Reprocessing for Government-Owned Spent Fuels

Author	Fuel Type and Amount	Disposal Method	Estimated Waste Production (for named inventory)
J.M. McKibben[7]	SRS-RBOF Special Fuels, all inventory (1.2 MTHM)	Direct Mass limited (≤ 1 kg HEU/canister)	640 Spent Fuel Canisters
		Reprocessing	15 HLW Canisters
R.H. Henry et al.[3]	ICPP Current Stockpile and Future 40-Year Receipts	Direct Mass limited (1.2 kg/canister)	69,040 Spent Fuel Canisters
		Unpoisoned (but limited to ~ 16 kg/canister)	8,939 Spent Fuel Canisters
		Poisoned (~ 22 kg/canister)	7,526 Spent Fuel Canisters
		Diluted	12,390 Spent Fuel Canisters
		Reprocessing	
		Aqueous only	8,640 HLW Canisters
		Aqueous and pyrometallurgical	285 HLW Canisters
L.W. Patrick[8]	SRS NPR-HWR, Lifetime of Reactor (31% HWR, Option G 2 batch)	Direct Unpoisoned	2,080 Spent Fuel Canisters
		Poisoned	693 Spent Fuel Canisters
		Diluted	139 Spent Fuel Canisters
		Partitioning-single stage	555 HLW (Fission products and diluted uranium)

2. The Yucca Mountain Repository

2.1 Site Characterization Plan

In December 1988, DOE published the *Site Characterization Plan [for the] Yucca Mountain Site, Nevada Research and Development Area, Nevada.*[1] The following quote is taken directly from Reference 1.

> The Yucca Mountain site has not been selected for a repository; rather, it has been designated as the only 'candidate site' to be characterized at this time. A comprehensive program of detailed investigations will be conducted at Yucca Mountain to determine whether it is suitable for a repository. If the site is suitable, then the DOE must demonstrate to the Nuclear Regulatory Commission (NRC) that the site meets regulations intended to protect the health and safety of the public both during repository operations and after the repository has been permanently closed. In order to demonstrate to the NRC that the repository system—that is, the site, the repository, and the waste package—would perform as required, the DOE must also develop designs for the repository and the waste package (i.e., the waste and the container in which it is packaged for disposal) and conduct scientific assessments to determine that the performance of the repository system would meet all applicable regulations.[1]

The following facts concerning the repository are also taken from Reference 1.

- The general guidelines for recommending suitable sites were issued by DOE in 10 CFR Part 960.

- The regulations for licensing geologic repositories by NRC were issued in 10 CFR Part 60.

- The environmental standards to manage and dispose of radioactive waste were issued by the Environmental Protection Agency in 40 CFR Part 191.

- Yucca Mountain is in southern Nevada in Nye County, about 100 miles by road northeast of Las Vegas. Parts of Yucca Mountain are on various federal lands: Bureau of Land Management of the Department of the Interior, Nellis Air Force Range (DOD), and the Nevada Test Site (DOE).

- The site lies in the southern part of the Great Basin—an arid region with little rainfall, sparse vegetation, and even sparser population. Northern Yucca Mountain is about 5000 feet above sea level, more that 1200 feet above Jackass Flats to the east, and more than 1000 feet above the eastern edge of Crater Flat to the west. The map depicted in Figure 1 is taken from Reference 1.

- At Yucca Mountain the water table lies as much as 2500 feet below the land surface.

- Yucca Mountain is underlain by a sequence of silicic volcanic rocks from more than 3000 to about 10,000 feet thick. The repository, if constructed, will be in an ash-flow unit called the "Topopah Spring Member". This unit is the lowermost and thickest of four units of the "Paintbrush Tuff".

2.2 Yucca Mountain Repository Conceptual Design

Reference 2 gives a conceptual design of the repository in summary form. Highlights of the design are:

- The surface facilities would receive the waste and prepare it for permanent disposal. Three types of surface facilities would be provided; (1) waste receiving and inspection, (2) waste operations, and (3) general support.

- The surface facilities would be connected to the underground facilities by two ramps and four shafts (shown on Figures 2 and 3).[1]

- The underground repository would be located about 1000 feet below the eastern flank of Yucca Mountain. An area of about 2095 acres would be available. Existing plans call for using 1380 acres. Figure 4 shows the conceptual layout of the emplacement "drifts".[1]

- The design assumes that waste containers would be emplaced in vertical boreholes drilled into the floor of the emplacement drifts. After a container was placed in the borehole, a metal plug of several inches would be emplaced to provide shielding. Crushed tuff would be placed on top of the shield. The borehole would than be sealed with a metal cover.

- Waste emplacement is scheduled for 26 years. A "caretaker" period of 24 years is then planned to ensure that the repository is performing as expected.

- For these 50 years, the waste is retrievable. Permanent enclosure requires sealing of all ramps, shafts, boreholes, and underground openings.

2.3 Details of the Yucca Mountain Program

In Reference 3, further detailed information on the Yucca Mountain program is given in the form of slide panels. These slides were presented at a meeting dated April 11 and 12, 1991, and are current as of that date. Pertinent excerpts from those panels are directly quoted in Figure 5.

3. Effect of Recent International Events on Reprocessing and Geologic Disposal

Under the assumption that reprocessing of defense-related spent fuels would continue, the planning for Yucca Mountain assumed that only commercial spent fuel and defense high-level waste in the form of glass logs would be emplaced. Indeed, the two Nuclear Waste Policy Acts stipulate only those two wasteforms.

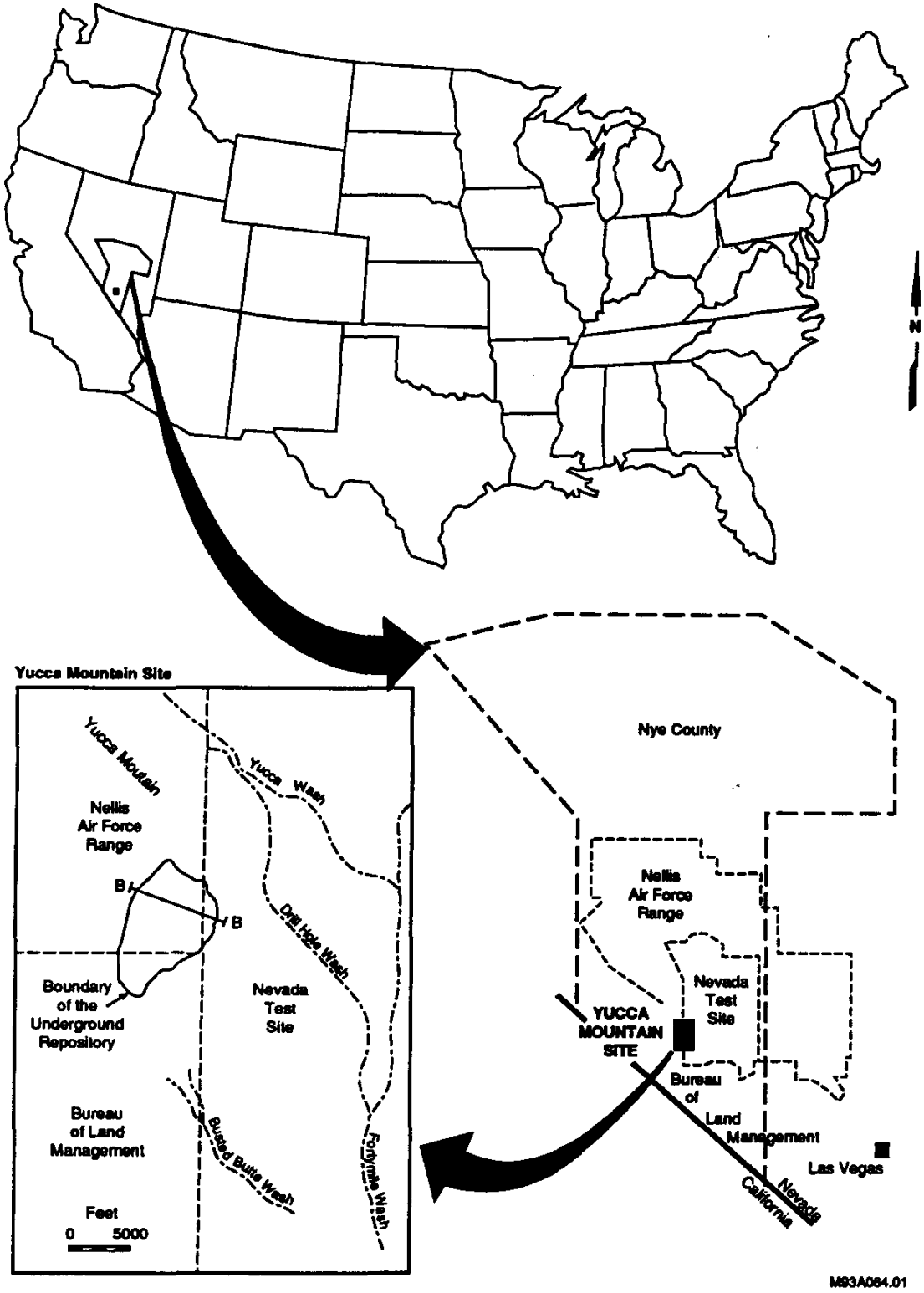

Figure 1. Location of the Yucca Mountain Site in Southern Nevada[1]

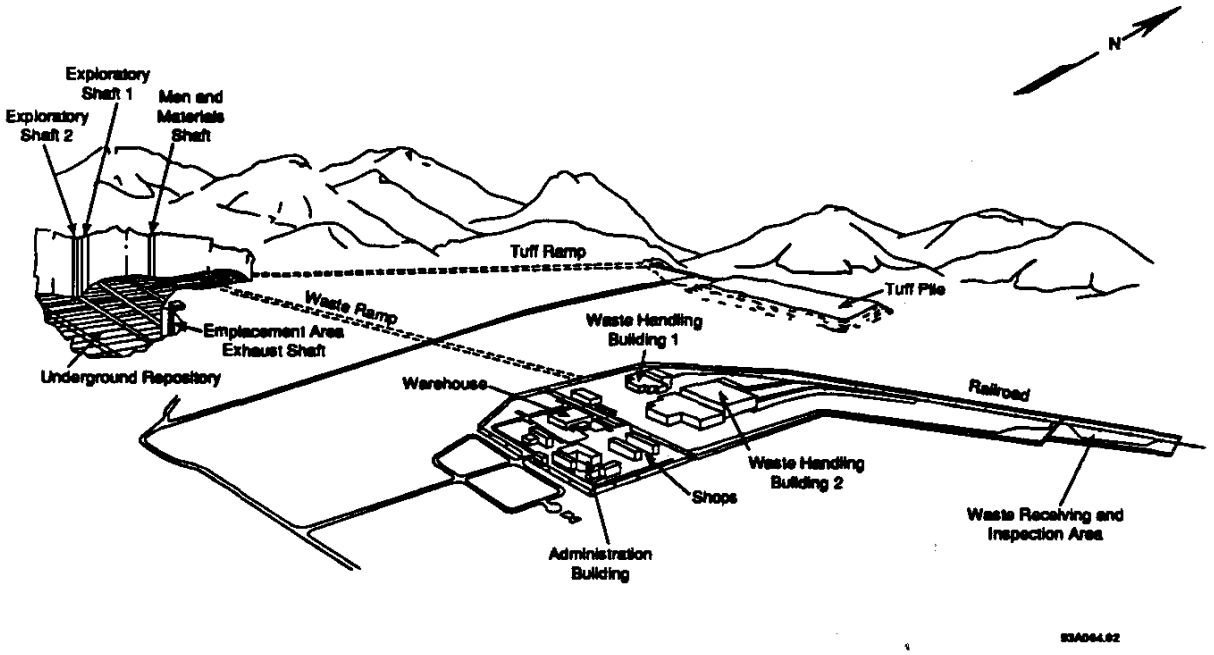

Figure 2. Perspective of the Proposed Repository at Yucca Mountain[1]

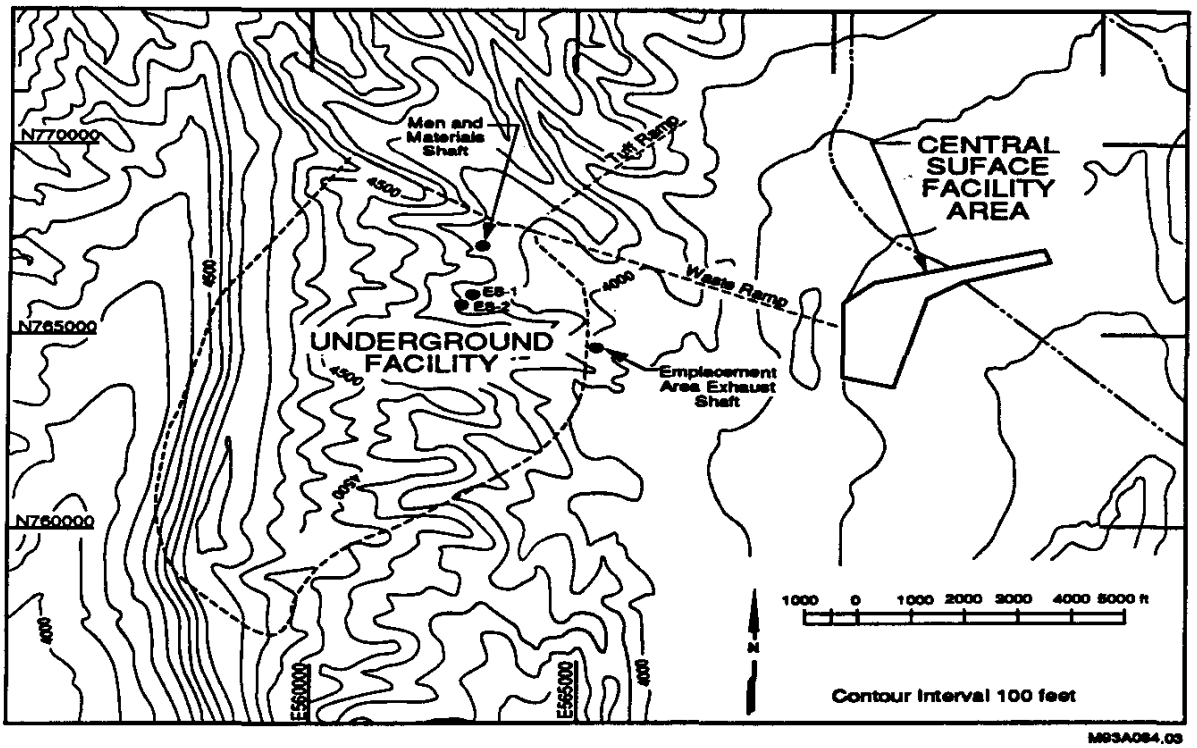

Figure 3. Topographic map showing the locations of the underground and the central surface facilities of the repository. The locations of the exploratory shafts are indicated by ES-1 and ES-2.[1]

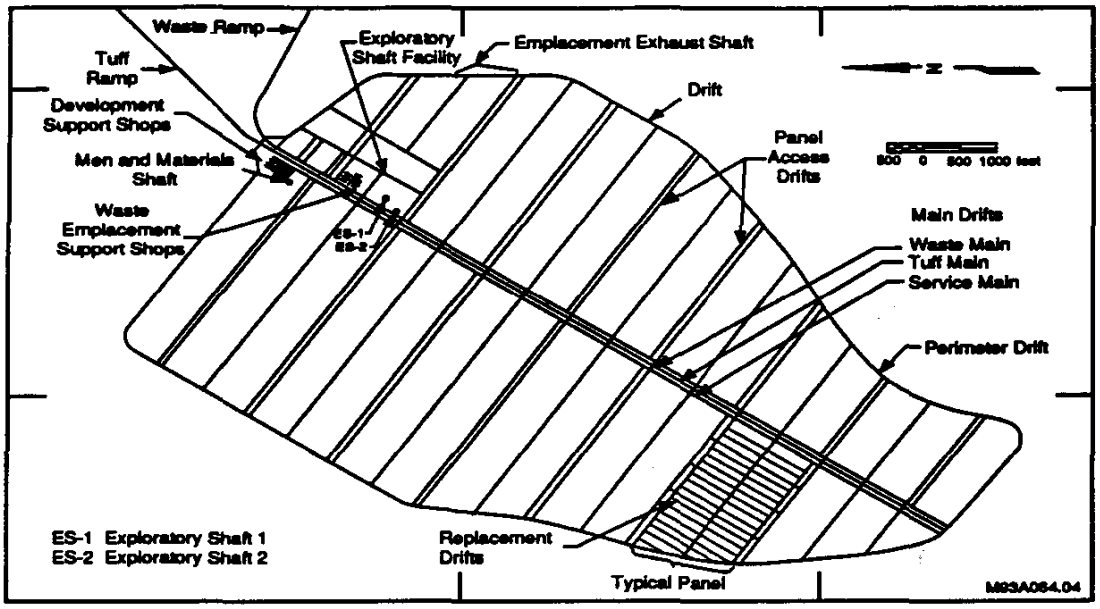

Figure 4. Underground Repository Layout for Vertical Waste Emplacement[1]

However, the recent agreements on the Strategic Arms Reduction Treaty (START), the previous tactical weapons agreement, and the encompassing political atmosphere have called into question the need for continued defense fuel reprocessing. An abundance of HEU will be available soon, depending on the weapons destruction schedule. This will occur in both the United States and the Commonwealth of Independent States (the former Soviet Union). In direct response to this situation, DOE has

- shut down the gaseous diffusion plants at Portsmouth
- shut down and ordered the Hanford Purex reprocessing facility into D&D
- shut down and ordered the Idaho Chemical Processing Plant into deactivation
- presented program execution guidance that the SRS H-Canyon and HB-Line facilities should process material only to convert existing liquid nuclear material stocks to a stable oxide form, and clean out the P-, K-, and L-Reactor disassembly basins and the RBOF basin for special fuels.

When such tasks are completed (estimated 1997), the H-Canyon and HB-Line facilities are to be deactivated.

DOE has also ordered K Reactor, the only remaining tritium production reactor still in operation, into standby beginning October 1993. However, the retention of qualified staff to guarantee the ability to restart K Reactor within the desired five-year period is known to be difficult. An extended period of slow operation of K Reactor has been recommended to provide incentives for qualified personnel to remain available for resumption of tritium production if required by future events. No decision on extended K-Reactor operation has been rendered by DOE to date and none is expected before mid-1993 at the earliest.*

* Note added during review. In March 1993, Secretary O'Leary made a press announcement to the effect that K Reactor would be placed in "cold standby". Details of this decision are now being formulated.

Schedules:

- Site Characterization Projected for Completion in 2001.
- DEIS in Oct-99 And FEIS in Late 2000.
- Repository Operation to Start in 2010 (Probably Will Slip to 2020).
  -Defense Waste Won't be Received Until 5 to 10 Years After Opening
- Director of OCRWM Can't Request Second Repository Until 2007 to 2010.
- MRS Can Not be Authorized Until NRC License to Construct Rep. is Issued.

Repository Configuration/Characteristics:

- 2,000 Acres Surface-400 Acres at Depth.
- Drifts-25 Feet High and 19 Feet Wide. Length Determined by Rock Formations. Drifts Are 120 Feet Apart.
- Heat Load is 50 KW/Acre (2,000) or 250 KW/Acre (Disposal Drift). Canisters Are Spaced 7 Feet Apart-Rock Mechanics.
- Horizontal Boring Rejected Because of Retrievability.
- Vertical Boring-Limited to About 20 Feet Depth; Diameter Sized for 26 Inch Commercial Package.

Figure 5. Details of the Yucca Mountain Program Pertinent to Direct Disposal of Spent Fuels [3]

Repository Capacity:

- By Law 70,000 MT of Heavy Metal Until Second Repository is Built.
- Actual Repository Capacity Won't Be Known Until Mining is Underway.
- 62,000 MTHM Commercial and 8,000 MTHM Equivalent Defense HLW.
- Accounting-One Canister Defense HLW = 0.5 MTHM — Commercial Generators Have Challenged Ratio.
- Oldest Commercial Fuel is First and Contracts Are in Place (Barter).
- Unless DOE Decides to Place Navy Fuel Ahead of Existing Defense Customers There Is No Room in The First Repository.
- Receipt Rate For Defense HLW May Be Limited To (8,000/62,000) × 2,300 MT/yr or 297 MTHM Equivalent/yr-SRS is at 200 MTHM Equivalent/yr.

Repository Economics:

- Several $100 Million Spent Already on Characterization.
- $180 Million/Yr is Current Budget.
- Site Characterization Costs = $2 billion Through 2001.
- TEC is Anticipated to be $9.1 Billion (1998 Dollars). [TEC, Total Estimated Cost]

  -$3 billion For Surface Facilities and Operations

  -$3 billion For Excavation

  -$3 billion For Placement and Closure
- Another $4.5 billion For Repository Licensing Cost.
- New Wasteform Characterization Studies Will Cost About $200 million And 5 Years to Complete.
- Other Development Costs Are Anticipated To Be About $450 million.

Figure 5. Details of the Yucca Mountain Program Pertinent to Direct Disposal of Spent Fuels[3] (Continued)

Thus, it is possible for SRS to accumulate additional K Reactor spent assemblies (Mark 22, Mark 60B, sparjet, and control rods). It is certain that spent naval fuel will continue to accumulate, possibly at ICPP.

In addition to the naval and production reactor fuels, DOE has extensive stocks of special nuclear fuels, which are left with no programmed means of disposal because of the reprocessing shutdowns. Direct disposal is being considered for all these stocks.

4. Suitability of Yucca Mountain for Direct Disposal of Defense Fuels

No research studies on the suitability of Yucca Mountain for the direct disposal of defense fuels are known to the author. However, in view of the then pending decision to shut down ICPP, personnel of that plant contacted DOE-RW, and others, in 1991 to explore the possibility of direct disposal of their spent fuels at Yucca Mountain. The following remarks, taken directly from Reference 3, distill those conversations.* Some of the opinions expressed below are contradictory. They have been included here to demonstrate that direct disposal of enriched spent fuels may be quite controversial and that assumptions about the decisions to be rendered are unsettled.

4.1 Observations of Mr. Carl Gertz, Project Manager, Yucca Mountain Site Characterization Office[3]

- **Legality of Navy Fuel Disposal**—Mr. Gertz briefly reviewed Section 8 of the NWPA-82 and said that the direct disposal of navy fuel was not specifically covered by this act, and, therefore, by statute could not be disposed in the repository without an amendment to the act. He said that his organization had not considered this disposal concept to date.

  This position is not in agreement with the position given by Ralph Stein that a new Section 8 Report could be prepared relatively easily. This position does support the report of a DOE-HQ activity to prepare a position paper to be reviewed by the Office of General Counsel and others on the legality of disposing spent defense fuels in a repository...

- **Repository Receipt Rate and Queuing**—I asked Mr. Gertz several questions on these topics. He said the Yucca Mountain site has not been fully characterized, and, thus, the size of the repository could only be estimated—that is, the total size of a useful geological formation has not been finalized. The NWPA-82 calls for a repository of 70,000 MTHM equivalent from commercial fuels and defense reprocessing waste. The size of the Yucca Mountain site (or any other site) cannot be made until areas within the geological formation are accessed through mining.

  The concept for Yucca Mountain is to receive waste canisters (spent commercial fuel or defense reprocessing waste) at a rate of 2000-3000 MTHM equivalent/yr with an average being about 2300 MTHM equivalent/yr for a period of 25-30 years. The anticipated receipt queue is: first commercial fuel out of reactor is the first fuel into the repository. He said the commercial people are paying for the repository by their 1 mil/kwh electric fee on an ongoing basis, and that DOE on an equivalent basis is several billion dollars behind. He said it would be hard to imagine a queue that did not have commercial fuels being emplaced first.

- **Criticality and Other Concerns**—We talked only in general terms about this topic. Mr. Gertz said the concept of having HEU in the repository did not set [sic] very well. This would complicate operating procedures and functional requirements of the repository, neither of which have addressed HEU to date. Also, he was concerned about public acceptance of HEU in the repository. He said they have a very large, ongoing program to gain acceptance, including detailed discussions of the waste to be emplaced. DOE's credibility could be damaged by now saying that a waste, not previously discussed or disclosed, would be emplaced in the repository. He believes that acceptance by the pub-

* There is no indication in Reference 3 as to whether these accounts of conversations have been reviewed by the named individuals.

lic would be greatly reduced. Mr. Gertz did not have any specific information on criticality calculations or specific concerns, such as time frame....

4.2 Observations of Unnamed Persons in the Yucca Mountain Site Characterization Project Office (YMSCPO)[3]

- The YMSCPO believes criticality is an important issue and that probability of public acceptance, and therefore, licensing, will be small if there is a potential for criticality anytime.
- Repository space for Navy fuels will not be available until 2020 at the earliest, and it may be in a second repository. Yucca Mountain is fully committed to commercial spent fuel and HLW defense waste.
- Director of OCRWM cannot request a second repository until 2007 to 2010. MRS cannot be authorized until NRC license to construct a repository is issued.
- Qualification development of new waste/package concepts will cost approximately $200 million and take five years.
- Disposal of naval fuel would impact the repository EIS and complicate NRC licensing process.
- Confidential fuel information would have to be provided to the NRC and may be made available to cleared intervenors in the licensing process.

4.3 Observations by Mr. Mike Valentine, Manager, Fuel Warranties and Site Services, Advanced Nuclear Fuel Corporation, Richland, WA[3]

- Industry is incorporating more storage capacity at reactor site because of uncertainty of repository staying on schedule or ever accepting commercial fuel.
- Criticality safety analysis for repository disposal of commercial fuel must be based on BOL (beginning of life) U-235 enrichments (commercial fuel enrichments now limited by license to less than 5%).
- Criticality prevention in the repository for commercial fuel relies on safe geometry (repository and individual fuel positions) and dry operating conditions (no neutron moderators). Accident scenarios must consider flooding and other events that could alter the geometry (repository or individual canister). Criticality prevention has not yet been a major repository issue, but may be a potential 'show stopper' when the issue is finally addressed.

4.4 Observations by Various DOE Personnel Contacted by Harry Chamberlain[3]

- Opinions on disposal of spent defense fuel differ greatly within DOE-RW. No agreement or position has been reached.
- No full agreement has been reached between DOE-RW and the NRC on disposal of spent commercial fuel.
- Disposal of spent defense fuel is a 'new ball game' for DOE-RW and the NRC. Costs for repository disposal cannot be assumed to be comparable to the costs for disposal of commercial fuel.
- DOE-NR Position:
  - Navy fuel can meet all commercial fuel disposal criteria.
  - Navy fuel contains no RCRA or hazardous materials.
  - Objections to disposal of intact Navy fuel can be easily met.
- DOE-RW Position:
  - Establishing requirements for defense fuel disposal will be long and costly.
  - Disposal costs for fuel may be greater than that for waste.
  - Accident scenarios must assume loss of canister integrity, water intrusion, and impact of volcanism.

4.5 Observations of Mr. Ralph Stein, formerly Associate Director for Regulations, Systems and Transportation (OCRWM)[3]

- Section 8 of NWPA is silent on anything related to spent defense fuel. The required President's report deciding to put defense HLW in the civilian repository

only focused on vitrified defense waste. Presently, DOE program people are split on whether another report addressing defense spent fuel is needed.

- The civilian fuel disposal program has a criticality issue, also, that has not been solved.

- The NRC would require confidential-restricted data details about Navy fuels before licensing their disposal. (Note: Yucca Mountain Projects people indicated such information could be provided to intervenors, by giving them clearance, in the licensing public review process.)

- If the repository opens in 2010, it will be 5 to 10 years (2015 to 2020) before it could start receiving Navy fuel.

- Mr. Stein doesn't think the NRC will require demonstrating criticality control for an indefinite time, but possibly for the quarternary period (2,000,000 years). However, the NRC has accepted the possibility of criticality in a sealed repository. Acceptability would be based on results of modeling the effects (i.e., migration of fission products).

- If the decision on disposal depends on 10,000 yr versus e.g., 10^6 yr, DOE-RW should get a determination from NRC of the applicable time.

- A December 1990 document considers that, in a single repository concept, 17,000 canisters of defense waste and 100,000 MTHM commercial fuel HLW would be received. Cost—$4 billion. All of defense waste may be 40,000-50,000 canisters. A second repository is inevitable.

4.6 Summary of Observations

The most important issues on the use of Yucca Mountain are:

- Direct disposal of HEU spent fuels was not specifically covered by NWPA-82 or its 1987 revision. An amendment to the act by Congress may be required to allow disposal of HEU spent fuels at Yucca Mountain.

- All space at Yucca Mountain is already reserved—62,000 MTHM for commercial spent fuel and 8,000 MTHM equivalent for defense HLW. Even if the space available at Yucca Mountain proves to be larger than 70,000 MTHM, there will be large amounts of HLW from future vitrification facilities and large amounts of commercial fuel still awaiting repository space.

- Repository space for defense HEU would require a second repository, which cannot be requested until – 2007-2010.

- Criticality would be considered a important issue for direct disposal of HEU spent fuel.
  - DOE-NR maintains essentially that criticality in a repository is a non-problem.
  - DOE-RW maintains that criticality may be 'show stopper'. NRC could demand that criticality control be maintained for up to 10^6 years. Public concern could easily overrule acceptance by NRC of criticality after <u>any</u> length of time.

- Commercial spent fuels have a criticality problem that is unresolved to date.

- DOE-RW is concerned about the damage to DOE's credibility that might result from saying that a waste, not previously discussed or disclosed, would be placed in the first repository (Yucca Mountain).

- Confidential information might have to be provided to NRC in support of direct disposal of naval fuels and would possibly be made available to intervenors with clearance in the licensing review process.

In the author's opinion, a prudent position would assume that HEU spent fuels could be placed only in a second repository, not Yucca Mountain. Greater weight should be given to the DOE-RW positions than to the DOE-NR on criticality. It is also noteworthy that none of the respondents

lic would be greatly reduced. Mr. Gertz did not have any specific information on criticality calculations or specific concerns, such as time frame....

4.2 Observations of Unnamed Persons in the Yucca Mountain Site Characterization Project Office (YMSCPO)[3]

- The YMSCPO believes criticality is an important issue and that probability of public acceptance, and therefore, licensing, will be small if there is a potential for criticality anytime.
- Repository space for Navy fuels will not be available until 2020 at the earliest, and it may be in a second repository. Yucca Mountain is fully committed to commercial spent fuel and HLW defense waste.
- Director of OCRWM cannot request a second repository until 2007 to 2010. MRS cannot be authorized until NRC license to construct a repository is issued.
- Qualification development of new waste/package concepts will cost approximately $200 million and take five years.
- Disposal of naval fuel would impact the repository EIS and complicate NRC licensing process.
- Confidential fuel information would have to be provided to the NRC and may be made available to cleared intervenors in the licensing process.

4.3 Observations by Mr. Mike Valentine, Manager, Fuel Warranties and Site Services, Advanced Nuclear Fuel Corporation, Richland, WA[3]

- Industry is incorporating more storage capacity at reactor site because of uncertainty of repository staying on schedule or ever accepting commercial fuel.
- Criticality safety analysis for repository disposal of commercial fuel must be based on BOL (beginning of life) U-235 enrichments (commercial fuel enrichments now limited by license to less than 5%).
- Criticality prevention in the repository for commercial fuel relies on safe geometry (repository and individual fuel positions) and dry operating conditions (no neutron moderators). Accident scenarios must consider flooding and other events that could alter the geometry (repository or individual canister). Criticality prevention has not yet been a major repository issue, but may be a potential 'show stopper' when the issue is finally addressed.

4.4 Observations by Various DOE Personnel Contacted by Harry Chamberlain[3]

- Opinions on disposal of spent defense fuel differ greatly within DOE-RW. No agreement or position has been reached.
- No full agreement has been reached between DOE-RW and the NRC on disposal of spent commercial fuel.
- Disposal of spent defense fuel is a 'new ball game' for DOE-RW and the NRC: Costs for repository disposal cannot be assumed to be comparable to the costs for disposal of commercial fuel.
- DOE-NR Position:
  - Navy fuel can meet all commercial fuel disposal criteria.
  - Navy fuel contains no RCRA or hazardous materials.
  - Objections to disposal of intact Navy fuel can be easily met.
- DOE-RW Position:
  - Establishing requirements for defense fuel disposal will be long and costly.
  - Disposal costs for fuel may be greater than that for waste.
  - Accident scenarios must assume loss of canister integrity, water intrusion, and impact of volcanism.

4.5 Observations of Mr. Ralph Stein, formerly Associate Director for Regulations, Systems and Transportation (OCRWM)[3]

- Section 8 of NWPA is silent on anything related to spent defense fuel. The required President's report deciding to put defense HLW in the civilian repository

quoted in Reference 3 seemed to consider it necessary to safeguard a repository just because it contained HEU spent fuels. Presumably, the "denaturing" of irradiated HEU that is caused by the presence of fission products and the build-in of U-236 and other minor actinides would make the material unsuitable for weapons use or render it too difficult to retrieve and transport. However, the naval fuel would surely require some form of safeguards to protect details of its fabrication.

5. Summary of Regulations Concerning Direct Spent Fuel Disposal in a Waste Repository

The specified regulations governing the site investigations, repository design, waste package requirements, and the repository closure have been issued by the Environmental Protection Agency, the Nuclear Regulatory Commission, and the Department of Energy. These regulations are reproduced in their entirety in Appendices A, B, and C for the convenience of the reader.

- Appendix A-40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes".

- Appendix B-10 CFR Part 60, Nuclear Regulatory Commission Requirements for "Disposal of High Level Radioactive Wastes in Geologic Repositories".

- Appendix C-10 CFR Part 960, DOE's "General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories".

5.1 EPA Standards

The important EPA standards may be summarized in the following direct quotations from 40 CFR, Part 191.

- Disposal systems...shall be designed to provide a reasonable expectation...that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal...shall

  1. Have a likelihood of one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

Table 1
Release Limits for Containment Requirements

(Cumulative releases to the accessible environment for 10,000 years after disposal)

Radionuclide	Release limit per 1,000 MTHM or other unit of waste (see notes)(curies)
Americium -241 or -243	100
Carbon-14	100
Cesium-135 or -137	1,000
Iodine-129	100
Neptunium-237	100
Plutonium-238, -239, -240, or -242	100
Radium-226	100
Strontium-90	1,000
Technetium-99	10,000
Thorium-230 or -232	10
Tin-126	1,000
Uranium-233, -234, -235, -236, or -238	100
Any other alpha emitting radionuclide with a half-life greater than 20 years	100
Any other alpha emitting radionuclide with a half-life greater than 20 years that does not emit alpha particles	1,000

  2. Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A) (see below).

- Disposal systems...shall be designed to provide a reasonable expectation that for 1000 years after disposal, undisturbed performance shall not cause the annual dose equivalent...to any member of the public in the accessible environment to exceed 25 millirems to the whole body or 75 millirems to any critical organ (assuming that exposed individuals consume 2 liters per day of groundwater outside of the controlled area).

It may be that DOE is having some difficulty in meeting these EPA standards or the public may be having difficulties in accepting them. The National Academy of Sciences (NAS) has been directed in the Energy Policy Act of 1992 to conduct studies to determine whether an acceptable health-based standard can be established based on exposure to individuals. The effect of post-closure oversight of the repository on the risk of breaching the engineered or geologic barriers will also be studied. The Academy will also address whether it is possible to make reliable predictions on the likelihood of breach of the repository by human intrusion for a 10,000-year period. In turn, the EPA is directed to issue new standards based on the NAS findings.*

5.2 NRC Regulations

The NRC Regulations are much more lengthy than the EPA standards. After some general provisions, Subpart B provides the licensing process that DOE must follow to gain the required NRC sanction to dispose of waste in the repository. Of particular note is Section 60.21 that details the content of application. Among other items, the following statements appear:

- The general information shall include...:
  - A certification that DOE will provide to the geologic repository operations area such safeguards as it requires at comparable surface facilities (of DOE) to promote the common defense and security.
  - A description of the physical security plan for protection against radiological sabotage. Since the radiation hazards associated with high-level wastes make them inherently unattractive as a target for theft or diversion, no detailed information need be submitted on protection against theft or diversion.

Subpart E addresses the Technical Criteria. Among the more interesting requirements appears the following:

- The following conditions are potentially adverse conditions..:
  - Earthquakes which have occurred historically, that if they were to be repeated, could affect the site significantly.
  - Indications, based on correlation of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.
  - More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

The earthquake requirements are particularly noteworthy in view of the fact that a 5.6 magnitude earthquake occurred on June 29, 1992, at a location only 12.5 miles southeast of the Yucca Mountain site. Several surface buildings were damaged at the site.

The general design criteria for the repository operations area include:

> *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (keff) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

5.3 DOE Guidelines

The DOE Guidelines address only site selection. Technical and policy issues like criticality and safeguards would be independent of site selection issues based on geologic properties, and thus, are not covered in the guidelines. A concise summary of the DOE concerns appears in Appendix

* Just prior to publication, EPA proposed a revised set of standards. In the main, the 25 millirem whole body limit would be reduced to 15 millirem, and the 1000-year period of application would be increased to 10,000 years.

III in tabular form, which is reproduced in this document as Table 2. The definitions of the numerical rating factors are also reproduced.

6.0 Spent Fuel Types and Inventories

6.1 Commercial Reactor Fuel

The amount of fuel already discharged from commercial nuclear reactors and projections of future fuel discharges are given in Reference 4. Table 3 is taken directly from Table 2-1 of Reference 4. An explanation of the assumptions behind the "end-of-reactor-life" and the "upper reference" cases is given below.

The DOE Office of Civilian Radioactive Waste Management (OCRWM) decided to make the no-new-reactor orders scenario the primary basis for its planning in 1988. The no-new-orders case is essentially based on nuclear plants operating now or under active construction. In effect, it assumes that the nuclear power era will cease when the last plant's license expires (~2037). This case is supported by the General Accounting Office and a consensus developed by OCRWM with the utility industry. Clearly, this case is the minimum bound for the amount of spent commercial fuel (assuming no premature plant shutdowns).

The "upper reference" case assumes that commercial nuclear power will continue to grow, doubling the current capacity by 2020 and reaching 25% of the total power generated in the U.S. The year 2020 is chosen arbitrarily as the end-year of the OCRWM study. Clearly, the cumulative weight (MTHM) of the discharged spent fuel will continue to grow beyond the 96,800 MTHM shown in Table 3.

Table 3 makes no distinction between the amounts of PWR and BWR fuel. From the standpoint of direct disposal, the problems posed by each fuel type are basically the same. Descriptions of the fuel assemblies and the anticipated isotopic contents are given in the later section on criticality studies that have been performed to date.*

6.2 Hanford Irradiated Fuel

The Hanford N Reactor was fueled with slightly enriched uranium at < 1.3 wt % U-235. When irradiated to its normal exposure, the plutonium produced during the enrichment had Pu-240 contents varying between 10 wt % and 16 wt % Pu-240, which characterized it as reactor-grade (or fuel-grade). Significant quantities were also characterized as weapons-grade plutonium because of smaller exposures and, hence, smaller Pu-240 contents.

Until September 1990, the planned disposition of the spent N-Reactor fuel was to reprocess it in the Hanford Purex plant to recover the plutonium and uranium stocks. At that time, the Purex plant was ordered into shutdown. The amount of unprocessed N-Reactor fuel remaining in the K-E and K-W disassembly basins totals to 2094 MT of uranium.[14] The average enrichment of the spent fuel is about 0.77 wt % U-235. Information on the number of individual assemblies is not given in Reference 14.

Except for the plutonium content of the fuel, the spent N-Reactor fuel has almost the same enrichment as natural uranium. However, because the fuel contains plutonium, criticality concerns may still exist.

Hanford does have additional spent fuels besides the N-Reactor stocks. The spent fuel from the Fast Flux Text Facility (FFTF) is currently stored in the reactor support facilities in the 400 Area at Hanford. This fuel is comprised of test assemblies with a wide range of fuel types—uranium carbide, uranium nitride, uranium-plutonium-zirconium alloy cladding. Approximately 2.9 metric tons of pre-1972 production reactor fuel (aluminum-clad uranium) remains in the 200 East Area and in the K-E and K-W Basins. Another 2.6 metric tons of miscellaneous fuel assemblies are in storage at low-level burial grounds or in the Waste Technology Engineering Laboratory (324 Building).

* Note: During review of this report the author's attention was drawn to a later source of commercial fuel data, DOE/RW-0006, Rev. 8. The numbers for the no-new-orders case are only slightly changed from those of Reference 4. The "upper reference case" was redefined.

Table 2
Finding Results From the Application of the Qualifying and Disqualifying Conditions of the Technical Guidelines for Major Siting Decisions

			Siting Decision		
Section	Guideline	Condition	Potentially Acceptable	Nomination and Recommendation	Repository Site Selection
4-1(a)	System	Qualifying		3	4
4-2-1(a)	Geohydrology	do		3	4
4-2-1(d)	do	Disqualifying		1	2
4-2-2(a)	Geochemistry	Qualifying		3	4
4-2-3(a)	Rock Characteristics	do		3	4
4-2-4(a)	Climatic Changes	do		3	4
4-2-5(a)	Erosion	do		3	4
4-2-5(d)	do	Disqualifying	1	1	2
4-2-6(a)	Dissolution	Qualifying		3	4
4-2-6(d)	do	Disqualifying	1	1	2
4-2-7(a)	Tectonics	Qualifying		3	4
4-2-7(d)	do	Disqualifying	1	1	2
4-2-8-1(a)	Natural Resources	Qualifying		3	4
4-2-8-1(d)(1)	do	Disqualifying	1	1	2
4-2-8-1(d)(2)	do	do		1	2
4-2-8-2(a)	Site Ownership and Control	Qualifying		3	4
5-1(a)(1)	System	do		3	4
5-1(a)(2)	do	do		3	4
5-1(a)(3)	do	do		3	4
5-2-1(a)	Population Density and Distribution	do		3	4
5-2-1(d)(1)	do	Disqualifying	1	1	2
5-2-1(d)(3)	do	do	1	1	2
	do	do		1	2
5-2-2(a)	Site Ownership and Control	Qualifying		3	4
5-2-3(a)	Meterology	do		3	4
5-2-4(a)	Offsite Installation and Operations	do		3	4
5-2-4(d)	do	Disqualifying	1	1	2
5-2-5(a)	Environmental Quality	Qualifying		3	4
5-2-5(d)(1)	do	Disqualifying		1	2
5-2-5(d)(2)	do	do	1	1	2
5-2-5(d)(3)	do	do	1	1	2
5-2-6(a)	Socioeconomic Impacts	Qualifying		3	4
5-2-6(d)	do	Disqualifying		1	2
5-2-7(a)	Transportation	Qualifying		3	4
5-2-8(a)	Surface Characteristics	do		3	4
5-2-9(a)	Rock Characteristics	do		3	4
5-2-9(d)	do	Disqualifying		1	2
5-2-10(a)	Hydrology	Qualifying		3	4
5-2-10(d)	do	Disqualifying		1	2
5-2-11(a)	Tectonics	Qualifying		3	4
5-2-11(d)	do	Disqualifying	1	1	2

"1" means *either* of the following:

(a) The evidence does *not* support a finding that the site is disqualified.

or

(b) The evidence supports a finding that the site is disqualified.

Table 2 (Contd)
Finding Results From the Application of the Qualifying and Disqualifying Conditions of the Technical Guidelines for Major Siting Decisions

"2" means *either* of the following:

(a) The evidence supports a finding that the site is *not* disqualified on the basis of that evidence and is *not* likely to be disqualified.

or

(b) The evidence supports a finding that the site is disqualified or is likely to be disqualified.

The findings resulting from the application of a qualifying condition for any particular guideline at a given decision point are denoted in the table by the numeral 3 or 4. The numerals 3 and 4 signify the types of findings that are required and are defined as follows:

"3" means *either* of the following:

(a) The evidence does not support a finding that the site is *not* likely to meet the qualifying condition.

or

(b) The evidence supports a finding that the site is *not* likely to meet the qualifying condition, and therefore the site is disqualified.

"4" means *either* of the following:

(a) The evidence supports a finding that the site meets the qualifying condition and is likely to continue to meet the qualifying condition.

or

(b) The evidence supports a finding that the site cannot meet the qualifying condition or is unlikely to be able to meet the qualifying condition, and therefore the site is disqualified.

Table 3
Projections of Nuclear Capacity and Spent Fuel Discharges[a]
(Thousands of metric tons of heavy metal)

	No-new-orders	End-of-reactor-life case		Upper Reference Case		
	Total net capacity[c]	Spent-fuel discharges[a,b]		Total net capacity[c]	Spent-fuel discharges[b]	
Year	(gigawatts)	Annual	Cumulative	(gigawatts)	Annual	Cumulative
1987	94		15.9	94		15.9
1988	95	2.0	17.9	95	2.0	17.9
1989	97	1.4	19.3	99	1.4	19.3
1990	97	2.0	21.3	103	2.0	21.3
1991	102	1.8	23.1	104	1.9	23.2
1992	102	2.1	25.2	104	2.2	25.4
1993	102	1.9	27.1	104	1.9	27.3
1994	102	1.8	28.9	104	1.9	29.2
1995	102	1.9	30.8	105	2.0	31.2
1996	102	1.9	32.7	107	2.0	33.2
1997	103	1.8	34.5	107	1.9	35.1
1998	103	2.0	36.5	107	2.1	37.0
1999	103	1.5	38.0	107	1.6	38.8
2000	103	2.2	40.2	107	2.2	41.0
2001	103	1.7	41.9	107	1.9	42.9
2002	103	2.0	43.9	106	1.9	44.8
2003	103	1.9	45.8	108	2.0	46.8
2004	103	2.0	47.8	108	2.0	48.8
2005	103	2.0	49.8	108	2.1	50.9
2006	103	1.9	51.7	114	1.8	52.7
2007	102	2.0	53.7	120	2.2	54.9
2008	102	1.9	55.6	126	2.1	57.0
2009	99	2.3	57.9	132	2.6	59.6
2010	97	2.2	60.1	138	2.9	62.5
2011	93	2.1	62.2	143	2.8	65.3
2012	89	2.1	64.3	149	3.0	68.3
2013	80	2.4	66.7	154	3.5	71.8
2014	69	2.5	69.2	160	3.9	75.7
2015	66	1.7	70.9	165	3.0	78.7
2016	60	1.6	72.5	170	3.8	82.5
2017	56	1.4	73.9	175	3.2	85.8
2018	55	1.4	75.3	180	3.7	89.5
2019	55	1.0	76.3	185	3.6	93.1
2020	51	1.1	77.4	189	3.7	96.8
2021		1.3	78.7			
2022		1.5	80.2			
2023		1.0	81.2			
2024		1.2	82.4			
2025		1.2	83.6			
2026		0.9	84.5			
2027		1.0	85.5			
2028		0.3	85.8			
2029		0.4	86.2			
2030		0.1	86.3			
2031		0.4	86.7			
2032		0.0	86.7			
2033		0.0	86.7			
2034		0.0	86.7			
2035		0.0	86.7			
2036		0.0	86.7			
2037		0.1	86.8			

[a]U.S. Department of Energy, Energy Information Administration, *World Nuclear Fuel Cycle Requirements 1988*, DOE/EIA-0436(88) (1988).
[b]Spent fuel discharge projections are based on an assumed 30% increase in fuel burnup by 2000.
[c]Source: U.S. Department of Energy, Energy Information Administration, *Commercial Nuclear Power: Prospects for the United States and the World*, DOE/EIA-0436(88) (1988).

6.3 Reactor Fuels at SRS

6.3.1 Production Fuel

Practically all the fuel still awaiting reprocessing and stored in the P-, L-, and K-Reactor disassembly basins is in the form of Mark 16 fuel tubes (3 tubes per assembly) and Mark 22 fuel tubes (2 tubes per assembly). The only parts of the assemblies that would either be reprocessed or subjected to direct disposal are the fuel tubes. The fuel tube inventory is given in Table 4. All of these fuels are uranium-aluminum alloys clad in aluminum at enrichments (post-irradiation) generally greater than 60%. (An appreciable number of Mark 31 depleted uranium slugs with significant plutonium built in by irradiation are awaiting processing in F Canyon.)

The present guidance from DOE-Headquarters calls for all of these assemblies to be processed through H Canyon and HB Line on a schedule to be completed by ~ 1997. However, no final decisions have been made and it remains possible that all or some of this inventory could be left for direct disposal. None of this fuel is considered suitable as a repository wasteform because it is clad in aluminum, has a metal core, and contains HEU. Significant pitting of the cladding already has occurred or would occur before the fuel could be transferred to either dry storage or a more closely controlled wet storage facility.

Table 4
Existing Production Fuel Inventory at Savannah River*

Location	Fuel Type	No. of Unprocessed Tubes
P-Reactor Basin	MK 16B	53 Outer 53 Middle 53 Inner
	MK 22	396 Outer 396 Inner
L-Reactor Basin	MK 16B	516 Outer 516 Middle 516 Inner
K-Reactor Basin**	MK 22	1332 Outer 1332 Inner

* Excluding incidental pieces of additional charges still in inventory (< 10).

** Including one charge which is scheduled for irradiation in early 1993.

According to the present Program Execution Guidance from DOE-Headquarters, K Reactor is scheduled for entry into standby beginning October 1993. However, concerns about the ability to guarantee a subsequent restart of K Reactor within five years of such a decision have prompted reconsideration of the Guidance. Reference 5 details options for various ways in which K Reactor could continue in operation with minimum fuel usage. No decision has been announced on extended K-Reactor operation. No reports concerning reprocessing for extended K-Reactor fuel inventories have been issued to date. (See footnote on page 9.)

The SRS production fuels were not designed for long-term storage in wet conditions (spent fuel pools) or dry conditions (interim storage or geologic repository). No studies have been performed on the suitability of the aluminum clad, uranium-aluminum fuel for dry storage. Reference 17 reviews the history of aluminum fuels corrosion in the production reactor disassembly positions. At least four cases of previous cladding penetration and fission product release are cited. Recommendations were made to improve the water chemistry control in the basins and eliminate galvanic couples, which can accelerate pitting corrosion.

6.3.2 Receiving Basin for Offsite Fuels

The Receiving Basin for Offsite Fuels (RBOF) was built at SRS to receive miscellaneous spent reactor fuels from various research reactors that are using DOE-owned fuel. The inventory as of October 1, 1991, is given in Reference 6. As much as 5 kg of U-235 stocks may have been added within the last year. The inventory is given in Table 5, which is a direct copy of the information in Reference 6.

As stated in Table 5, a significant portion of the irradiated fuel in RBOF is scheduled for reprocessing in either H Canyon or F Canyon. However, the majority of the fuel forms are not processable unless additional steps are taken to add capability to H Canyon. Reference 7 recommends restoring the electrolytic dissolver capability to H Canyon at a cost of $5-$10 million. This step should allow processing of all of the non-processable fuels with the addition of two years to the schedule already announced for the phase-out of H Canyon in the 1992 Program Execution Guidance from DOE. However, DOE is not considering restoration of the electrolytic dissolver at this time.

Table 5
SRSNonproduction Fuel Inventory [6] (as of October 1, 1991)

Reactor	Percent U-235 Enrich	Description	U-235 (KG)	Plutonium (kg)	Available for Processing	Process-Ability (1)
Aluminum Fuels						
Sterling Forest Oxide	93.19	UO_2, Al CAN	98.760	-	1990, 221-H	B
Sterling Forest Fuel	77.48	UAl, Al CLAD	2.343	-	1990, 221-H	A
Nereide	19.79	UAl-Six AL CLAD	7.015	-	Not Scheduled	E2
HFIR	86.10	UAl, Al CLAD	0.000	-	1990, 221-H	A
RHF	81.97	UAl, Al CLAD	20.775	-	1990, 221-H	A
TRR	0.60	U METAL, Al CLAD	88.368	11.706	1990, 221-F	A
EBR-II	0.19	U METAL, Al CAN	42.000	76.135	Not Scheduled	A
HFR	76.34	UAl, Al CLAD	0.000	-	1990, 221-H	A
JMTR-JRR	88.17	UAl, Al CLAD	14.795	-	1990, 221-H	A
ESSOR	83.19	UAl, Al CLAD	0.000	-	1990, 221-H	A
ORR	82.20	UAl, Al CLAD	16.932	-	1990, 221-H	A
DR-3	76.30	UAl, Al CLAD	0.000	-	1990, 221-H	A
ORR-LEU	15.75	U_3Si_2, Al CLAD	14.960	-	Not Scheduled	E2
WPI	93.40	UAl, Al CLAD	3.784	-	1990, 221-H	A
OSU	93.19	UAl, Al CLAD	0.394	-	1991, 221-H	A
SS Fuels						
Carolina Virginia Tube Reactor	0.95	UO_2, Zr OR SS CLAD	0.640	0.200	Not Scheduled	E2
High Temperature RX Experiment	92.57	UO_2, BeO, NICHROME CLAD	3.423	-	Not Scheduled	C
Saxton Pa. Reactor	0.54	UO_2, PuO_2, Zr & SS CLAD	1.411	15.408	Not Scheduled	E1
	10.14	UO_2, Zr	6.866	0.233	Not Scheduled	E2
Experimental Boiling Water Reactor	93.29	UO_2, SS CLAD	1.612	-	Not Scheduled	C
	5.95	UO_2, Zr CLAD	95.456	-	Not Scheduled	E2
	1.47	U-Zr, Zr CLAD	73.967	9.092	Not Scheduled	E2
	92.12	UO_2, ZrO_2 CaO, Zr CLAD	26.651	-	Not Scheduled	E2
	0.23	UO_2, PuO_2, Zr CLAD	2.087	13.940	Not Scheduled	E2
Gas Cooled Rx EXP (GCRE)	92.28	UO_2 or UO_2-BeO HASTELLOY CLAD	56.559	-	Not Scheduled	C
Mobile Low Power Reactor (ML-1)	93.01	UO_2 & UO_2-BeO	54.478	-	Not Scheduled	C
Babcock & Wilcox Scrap	52.00	UO_2, PuO_2, SS CLAD	0.013	0.048	Not Scheduled	E1

Table 5 (Part 2)
SRS Nonproduction Fuel Inventory[6] (as of October 1, 1991)

Reactor	Percent U-235 Enrich.	Description	U-235 (KG)	Plutonium (kg)	Available for Processing	Process-ability (1)
Heavy Water Components Test	0.96	U & UO_2 Zr CLAD	9.470	0.565	Not Scheduled	E2
	85.00	U-Zr, Zr CLAD	31.590	-	Not Scheduled	E2
Dresden Power Reactor	5.49	UO_2, ThO_2, SS CLAD	37.545	1.879	Not Scheduled	E2
Elk River Reactor (ERR)	83.00	UO_2, ThO_2, SS CLAD	186.159	-	Not Scheduled	E2
Oak Ridge National Lab (ORNL)	92.93	U-Zr CLAD	0.171	-	Not Scheduled	E2
Canadian Deuterium RX	0.46	UO_2, Zr CLAD	0.231	-	Not Scheduled	E2
Special Power Excursion RX Test	4.77	UO_2, Zr CLAD	0.603	-	Not Scheduled	E2
Vallecitos Boiling Water RX	24.72	UO_2, Zr CLAD	1.243	0.003	Not Scheduled	E2
Robinson Fuel	0.72	UO_2, PuO_2, ZR CLAD, SS Casing	0.004	0.003	Not Scheduled	E2
ORNL Mixed Oxide	7.90	UO_2, PuO_2, ZR, SS CLAD	0.030	0.094	Not Scheduled	E2
EBR-2 (HEDL)	79.73	UO_2, PuO_2, SS CLAD	1.624	0.680	Not Scheduled	E2
EBR-2 (ANL)	85.84	UO_2, PuO_2, SS CLAD	0.376	0.114	Not Scheduled	E2
SRE	9.16	UC, SS CLAD	4.344	0.016	Not Scheduled	D
SRE	92.38	UO_2, ThO_2, SS CLAD	143.410	-	Not Scheduled	E2
LWR Samples	1.52	UO_2, PuO_2, SS & Zr CLAD	0.192	0.109	Not Scheduled	E2
Shipping port	0.14	UO_2, Zr CLAD	0.023	0.108	Store Only	NA
EPR-1	0.00	PuO_2, SS CLAD	-	0.022	Not Scheduled	E2
		Total SS Fuels	740.178	42.514		
		Total Al Fuels	310.126	87.841		
		Totals	1050.304	130.355		
		Change From Last Inv.	2.594	.547		

(1) Processability codes are as follows:

A. Processing authorized in existing facilities
B. Processable in existing facilities pending test authorization approval
C. Processable with modification of existing facilities (capital expenditures required for specifically defined modification)
D. Processable in existing facilities, pending satisfactory resolution of technical and/or safety questions
E. Not processable in existing facilities
   (1) Processing requires new facility (major capital expenditure)
   (2) Processing scheme undefined (development effort required)

6.4 DOE Reactor Fuel at the Idaho Site and Elsewhere

Table 6 shows the 1989 inventory of stored fuels at all sites except Hanford (N Reactor) and SRS.[16] The inventory of spent naval fuel at ICPP is not included in this listing.

6.5 Possible Future Reactor Fuels

A proposal has been made to DOE that the excess plutonium stockpile be disposed of by burning it in light-water reactors. In Reference 8, the use of MOX fuel in advanced LWR is proposed. A postulated 50 MT of excess plutonium could be denatured in 40 years by burning it in two or three reactors of the 600-MW_e size. A single such reactor would consume plutonium at the rate of about 560 kg per year. This translates, at 3.3% enrichment (plutonium vs. U-238), to about a 19 MTHM throughput per year. Thus, with three 600-MW_e reactors, the discharge rate could be as high as 57 MTHM per year. However, DOE has rendered no decision on the proposal. It and other such proposals for disposal of excess plutonium are currently under study in DOE-NE and the National Academy of Sciences.

7.0 Criticality Studies and Proposed Solutions

The half-life of U-235 is 7×10^8 years. In effect, a criticality risk of some magnitude will exist forever for any assemblage of this isotope above a critical mass, at least in human terms. Opinions differ, but observers quoted in Section 4 seem to agree that criticality will have to be prevented for a long time, perhaps 1-2 million years. This is far beyond the 1,000-10,000 year requirements mentioned in the NRC regulations for canister integrity. No decision by regulators has been reached concerning the acceptability of a criticality event in a sealed repository.

The following discussions of proposed solutions attempt to evaluate the risk of criticality for each option. Only reprocessing can reduce the repository risk to zero. However, there are direct disposal options that could reduce the risk to as low as provided by nature for the prevention of criticality in ore stocks.

The only way that natural uranium can "go critical" is for a light moderator such as graphite or beryllium to intersperse itself through the core. Heavy water of the concentration required for a natural uranium concentration to yield a critical event does not exist in nature. The odds of such an arrangement of moderator and natural uranium must be extremely low. It is inconceivable that a reduction of the U-235 enrichment to that of natural uranium would not be accepted as proof that criticality was prevented.

An exposition of the criticality issue has been assembled by R. L. Nebeker of the Idaho National Engineering Laboratory. This appraisal has been reproduced in whole as Appendix D of this report.

The following discussion presents the criticality analyses that have been performed to date for commercial fuel, for naval fuel, and for NPR fuel (very similar to the fuel tubes used in the present SRS reactors). These studies range over the entire spectrum of criticality risks that can exist in spent fuel.

7.1 Commercial Spent Fuel

Several sets of criticality calculations have been performed for various waste canister designs with various amounts and configurations of commercial spent fuel. Three are known to the author and listed in References 11-13. The last of these three reports (Reference 13) covers the most varied of the "pre-closure" scenarios that could be possible. The first of the three (Reference 11) has some "post-closure" as well as pre-closure scenarios. Reference 12 gives a plethora of detail about the standards and regulations applicable to criticality calculations and the methodology to be used, but gives the results of only one criticality calculation. All three references show scenarios for which criticality is possible.

Reference 11 makes the claim that while the use of beginning-of-life (BOL) isotopic contents will result in several critical scenarios (defined when $k_{eff}>0.95$, including biases and uncertainties), the use of actual depleted isotopic contents will prevent criticality. This statement is refuted by the wider studies of Reference 13 where instances of criticality ($k_{eff}>0.95$) were demonstrated even with end-of-life isotopics. The leachability of fission product poisons could raise k_{eff} in time even higher.

7.1.1 Pre-Closure Results

Figure 6 shows the k_{eff} values calculated for 14 specific water flooded scenarios.[13] All of these cases assumed intact containers and canisters as would be the case prior to closure. All of the dry cases were known to be subcritical by large margins because the enrichment was always less than 5%. With these low enrichments, an unmoderated criticality is not possible. A k_{eff} value of >0.95 is exceeded

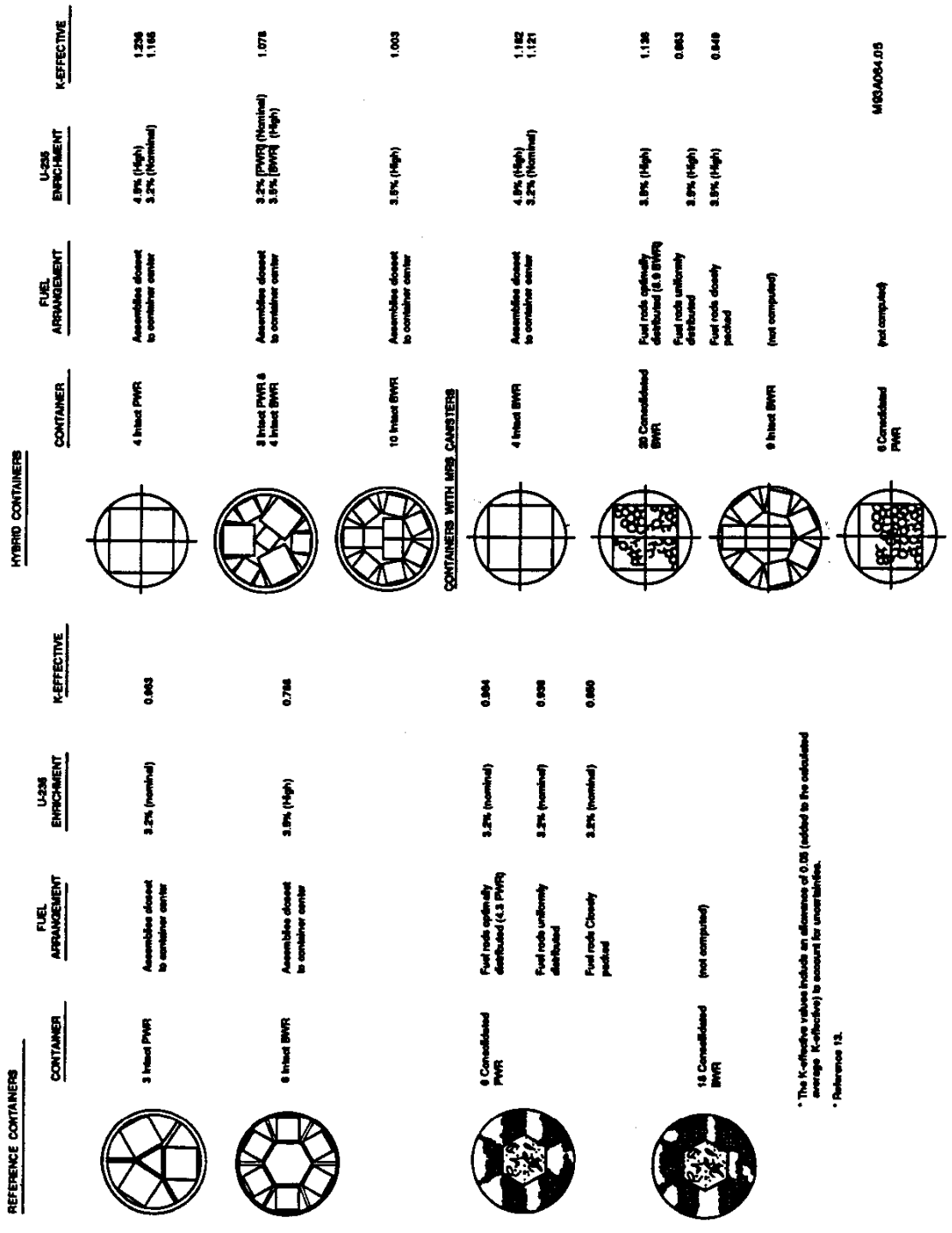

Figure 6. Results of Flooded-Preclosure Criticality Calculation[13]

Table 6
Inventory of Stored Fuels[16] (October 1989, Excluding Naval Fuels) (1 of 5)

Source of Material	Composition[b]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Defense plus other government agency material stored at ICPP (INEL)								
GCRE (Gas-Cooled Reactor Experiment)	UO_2-BeO, Hastelloy X clad	One SS tube, 5 in. × 25.5 in.		0.984	0.918			
LWBR (Shippingport Light-Water Breeder Reactor)	Ceramic pellets, Zr-clad, Th blanket	65 units		982.173	10.349	826.016	0.177	56,167.0
Misc. fuels and scrap	Scrap	Stored in 92 SS and Al cans		168.195	137.330	0.119	0.079	36.0
PWR Core 2 (Shippingport Pressurized Water Reactor)	UO_2 pellets, Zr-clad	28 units		392.026	305.802			
SM-1A (Stationary Media)	UO_2, SS-clad	Stored in 93 SS cans		65.759	56.648			
TORY-11A	UO_2, BeO crushed to 0.25 in. × 0.06 in.	Stored in 147 Al cans 3.25 in. × 1.5 in.		48.645	45.325			
TORY-11C	UO_2-Y_2O_3-ZrO_2-BeO ceramic	Stored in three Al cans 2.68 in. × 52.5 in.		59.065	55.022			
Subtotal				1,716.847	611.394	826.135	0.256	56,203.0
DOE/Civilian Development Programs material stored at ICPP (INEL)								
EBR Scrap (Experimental Breeder Reactor)	Scrap			1.618	0.839			
Fermi 1 Blanket	U-Mo (97% U), sodium-bonded, SS-clad	Stored in 510 SS cans 0.4-in. diam × 41 in. or 61 in.		34,165.000	120.000		6.522	
FSVR (Fort St. Vrain Reactor)	U-Th carbide and Th carbide pyrolytic carbon coated particles in graphite matrix	732 hexagonal graphite blocks 14.2 in. across flats × 31.2 in.		299.758	164.431	87.013	0.752	8,124.0
Pathfinder	UO_2-B_4C pellets, SS-clad	417 rods in 17 cans; each can is 9-in. diam × 80 in.		53.406	49.242			

Table 6. Inventory of Stored Fuels (October 1989)

Table 6
Inventory of Stored Fuels[16] (October 1989, Excluding Naval Fuels) (2 of 5)

Source of Material	Composition[b]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program material stored at ICPP (continued)								
Peach Bottom	U-Th carbide, Pyrolytic carbon-coated particles in graphite matrix	1,603 graphite blocks 3.5-in. diam × 12 ft	>1[c]	332.420	223.540	46.310	0.970	2,620.0
Pulstar, State University of New York at Buffalo	UO_2 pellets in Zr-clad pins	Stored in 24 SS cans, 3 in. × 3 in. × 35.5 in.		251.431	12.083		0.793	
TRIGA (Training Reactor, Isotopes, General Atomic)	Al- or SS-clad elements	852 units stored in 121 cans		160.974	33.839			
VBWR (Geneva) (Vallecitos Boiling-Water Reactor)	UO_2 and UO_2-TiO_2, SS-clad	142 rods stored in four 6-in.-diam × 36-in. Al cans	8[c]	12.383	2.606			
Subtotal				35,276.990	606.580	133.323	9.037	10,744.0
DOE material stored at NRF[d]								
Shippingport PWR Core 1	UO_2 pellets, Zr-clad	Seed and blanket fuel assemblies	11,100	570.02	1.63		3.4	
Shippingport PWR Core 2	UO_2 wafers, Zr-clad	Seed and blanket fuel assemblies	14,273	1,260.92	164.45		8.9	
Subtotal				1,830.94	166.08		12.3	
DOE/Civilian Development Programs material stored at INEL (other than ICPP and NRF)								
CANDU (Canadian Deuterium Reactor	UO_2 pellets, Zr-clad	8 pins	5,000	2.660	0.261			
Connecticut Yankee	UO_2, Zr-clad	1 assembly		378.485	5.204		3.774	
Dresden	UO_2, Zr-clad	54 pins (depleted U)		165.0	Unknown		1.064	
EMAD[e] (Engine Maintenance Assembly & Disassembly)	UO_2 pellets, Zr-clad	18 assemblies	25,000-30,000	7,831.273	58.103		65.255	
GAP CON (Gap Conductance)	UO_2 pellets, Zr-clad	20 pins	42-115	12.838	1.285			

Table 6
Inventory of Stored Fuels[16] (October 1989, Excluding Naval Fuels) (3 of 5)

Source of Material	Composition[b]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program material stored at INEL, (Other than ICPP and NRF) (continued)								
GE (General Electric)	UO_2 pellets, Zr-clad	Pins		18.644	0.394		0.071	
Halden Assay	UO_2 pellets, Zr-clad	5 pins	4.000	2.313	0.233		0.005	
Halden 226 and 239 Assy	UO_2-PuO_2 pellets, Zr-clad	12 pins					0.324	
IE (Irradiation Effects)	UO_2 pellets, Zr-clad	Pins	27-17.600	7.833	0.867		0.012	
LLR (LOFT Lead Rod)	UO_2 pellets, Zr-clad	7 pins	36-150	3.510	0.327			
LOC (Loss of Coolant)	UO_2 pellets, Zr-clad	60 pins	16-150	7.777	0.816		0.010	
LOFT (Loss of Fluid Test)	UO_2 pellets, Zr-clad	15[c] assemblies	0-1,050	2,201.696	89.371		2.029	
MAPI (Mitsubishi Atomic Power Industries)	UO_2 pellets, Zr-clad	43 pins	2,990-8,770	22.499	1.267		0.032	
Miscellaneous fuel pins	UO_2 pellets, Zr-clad	Pins	Varies	173.354	1.758		2.626	
Miscellaneous rods and scrap	Scrap	Stored in 8 cans	Varies	13.553	1.197			
OPTRAN (Operational Transient)	UO_2 pellets, Zr-clad	Pins	0-15,000	19.669	0.472		0.087	
PBF (Power-Burst Facility)	UO_2-ZrO_2-CaO; Zr sleeves, SS-clad			725.690	132.890			
PCM (Power Coolant Mismatch)	UO_2 pellets, Zr-clad	30 pins	<70	18.828	6.557			
Peach Bottom	UO_2 pellets, Zr-clad	1 assembly and pieces		364.1	2.512		1.878	
RIA (Reactivity Initiated Accident)	UO_2 pellets, Zr-clad	23 pins	0-6,090	8.989	0.504		0.013	
H. B. Robinson	UO_2 pellets, Zr-clad	Pins	28,000	263.916	1.890		2.153	
Saxton	UO_2 pellets, Zr-clad	21 Pins	10,400-18,530	7.607	0.660		0.025	
SFD (Severe Fuel Damage)	UO_2 pellets, Zr-clad	143 pins		50.867	2.711		0.150	
TC (Thermocouple)	UO_2 pellets, Zr-clad	Pins	0-<20	6.186	0.683			
TMI-Unit 2	Rubble		(Quantities unknown until entire core received)					
VEPCO (Virginia Electric Power Co.)		69 assemblies		30,207.295	242.457		172.695	
Subtotal				42,514.582	552.419		252.203	
Total at INEL				81,339.359	1,936.473	959.458	273.796	66.947.0

[a]See refs. 10-11. Many of the fuels at INEL have lower uranium enrichment than is found in those fuels that are normally processed. These fuels could be reprocessed in a special campaign, if required.
[b]Zr-clad-Zircaloy-clad.
[c]Data expressed in percentage.
[d]Turkey Point Fuel.

Table 6. Inventory of Stored Fuels (October 1989) (continued)

Table 6
Inventory of Stored Fuels[16] (October 1989, Excluding Naval Fuels) (4 of 5)

Source of Material	Composition[b]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
Miscellaneous Radioactive Materials Stored at Los Alamos Nat. Lab (Dec. 1989)								
EBR-2	U-Pu oxide, carbide or nitride SS-clad fuel rod segments	0.3-in. diam × 13.5 in.[a]		26.08	17.71	0.134	6.35	
B&W (Lynchburg, VA)	UO_2 spent fuel elements	Stored in racks		5.60[b]	4.74	____	____	
Total				31.68[ab]	22.45	0.134	6.35	

[a]No information regarding the burnup of this fuel is available.
[b]Includes 0.348 kg of ^{236}U.

Source of Material	Composition[b]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
Miscellaneous Radioactive Materials Stored at Oak Ridge Nat. Lab (Dec. 1989)								
CEU (Consolidated Edison Uranium)	U_3O_8-CdO solid cake	Stored in 401 3.5-in.-OD × 24-in. SS cans	b	1,044.38	797.70	101.32		
Dresden-1	UO_2, Zr-clad	Sheared fuel pins stored in two 1-qt paint cans	~24,000	5.00	0.024		0.020	
		9/16-in.-diam × 8-in. fuel rod sections plus short lengths	20,000	0.930	0.005		0.006	
GETR (General Electric Test Reactor)	UO_2, Zr-clad	9/16-in.-diam × 8-in. fuel test capsules	1,000-2,000	0.399	0.022			
Monticello	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008	
MSRE[c] (Molten Salt Reactor Experiment)	LiF_2-BeF_2-ZrF_2-UF_4	~5×10^4 Ci total	36.95	0.940	31.01	0.743		
Oconee-1	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	38,000	1.00	0.005		0.005	
Peach Bottom-2	UO_2, Zr-clad	9/16-in.-diam × 8-in. fuel rod sections plus short lengths	10,000	0.324	0.001		0.001	

Table 6. Inventory of Stored Fuels (October 1989) (continued)

Table 6
Inventory of Stored Fuels[16] (October 1989, Excluding Naval Fuels)(5 of 5)

Source of Material	Composition[a]	Description	Estimated burnup (MWd/MTHM)	U Content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program material stored at INEL, (Other than ICPP and NRF) (continued)								
Quad City-1	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008	
H. B. Robinson	UO_2, Zr-clad	1/2-in.-diam × 12-in. fuel rod sections plus short lengths	30,000	1.00	0.005		0.004	
BR-3 (Belgium)	UO_2, Zr-clad	3/8-in.-diam × 6-in. fuel rod lengths	42,000	0.837	0.020		0.006	
ORNL Inventory Item Nos.								
AUA-67/AUA-70 from LANL	U metal chunks	Stored in two 3.75-in.-OD × 18-in. SS cans	b	6.02		5.89		
CZA-91 from ANL	UO_3 powder	Stored in two 3.5-in.-OD × 13-in. SS cans	b	0.881		0.856		
HUA-2A from HEDL	UO_3 powder	Stored in five 3.75-in.-OD × 7-in. SS cans	b	0.317		0.307		
LAE-03	Metal	Stored in one 3-in. OD × 10-in. SS can	b	0.01		0.01		
RCP-02 from SRO	UO_2 powder	Stored in thirty–two 3.5-in.-OD × 24-in. SS cans	b	11.14		10.72		
RCP-03 from SRO	UO_2 powder	Stored in 140 3.88-in.-OD × 10-in. SS cans	b	67.41		61.61		
RCP-04 from SRO	UF_4-LiF_2 powder converted from UO_2	Stored in six 3.5-in.-OD × 24-in. SS cans	b	3.19		2.92		
RCP-06	U_3O_8-CdO solid cake	Stored in twenty–seven 3.5-in.-OD × 24-in. SS cans	b	65.55		60.60		
RCP-20/JZBL from LANL	U metal chunks	Stored in five 3.5-in.-OD × 24-in. SS cans	b	5.15		5.05		
Total				1,252.92	798.7	280.29	0.801	

[a]Zr–clad = Zircaloy-clad.

[b]No information regarding the burnup of this fuel is available.

[c]The Molten Salt Reactor Experiment was concluded in 1969, and the fuel has never been removed from the facility. A surveillance and monitoring program has been in force since shutdown. Decommissioning of the MSRE facility is an environmental restoration activity.

for 9 out of the 14 flooded cases. Clearly, the amount of fuel in the canisters will have to be limited, or neutron poisons will have to be added to each canister, to avoid criticality under all pre-closure scenarios.

Several qualifiers were attached to these results by the authors.[13]

- Uncertainty analyses of the k-effective calculations are necessary in order to determine whether some of the container designs and fuel arrangements can meet the criticality safety requirements...
- The k-effective values of some container designs considered in this study may be reduced to less than 0.95 if credit is taken for burnup of spent fuel. This issue should be evaluated in future studies.
- The k-effective of containers and fuel arrangements not considered in this study should be evaluated. Any changes in present container designs or fuel arrangements will necessitate the reevaluation of the k-effective.
- A more in-depth investigation of the impact on k-effective of the hardware in the central cavity of a container should be made.
- As the repository design evolves and more information becomes available, the major assumptions adopted in this study should be reexamined. In addition to the fully flooded containers considered in this report, other possible water densities and assumed parameters should be evaluated in more detail.
- Criticality safety analyses for the post-closure period should be performed to evaluate potential effects of water intrusion and degradation of the container and spent fuel structures.

7.1.2 Post-Closure Results

Under post-closure conditions, the canister could crumble away, the container and fuel cladding could be destroyed, and the pellets could fall together or even be reduced to powder in the bottom of the borehole. Clearly, this would take place over hundreds to thousands of years. The flooding of various arrays of such disordered material could occur with a sufficiently large seismic event or from opening of a shaft to a surface water supply. No effort was made to justify any of the events postulated above in Reference 11 or 13.

The reference fuel in Reference 11 was unirradiated fuel rods (BOL) from six Westinghouse PWR standard 17 × 17 fuel assemblies containing UO_2 fuel pellets enriched to 4.5 wt % U-235. The container of the fuel rods is shown in Figure 7. The canister and borehole are shown in Figure 8. Seven calculations were made for four configurations of the fuel, cladding, container, and canister. The identifying configuration numbers and the description are taken from Reference 11.

- Configuration 1—Nominal-dry
- Configuration 2—Nominal-flooded
- Configuration 6—Container and canister partially gone-flooded
- Configuration 10—Clad and disintegrated pellets (powder) optimally mixed-flooded

The enrichments for configurations 6 and 10 were varied to

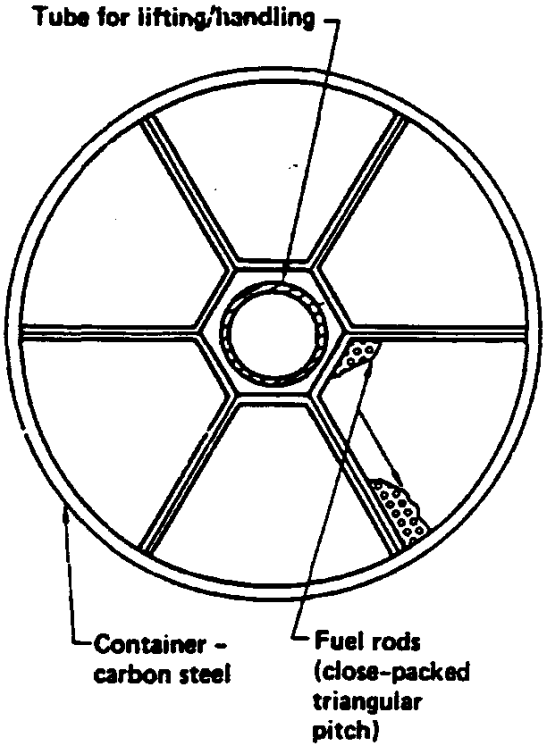

Figure 7. Spent Fuel Container Cross Section

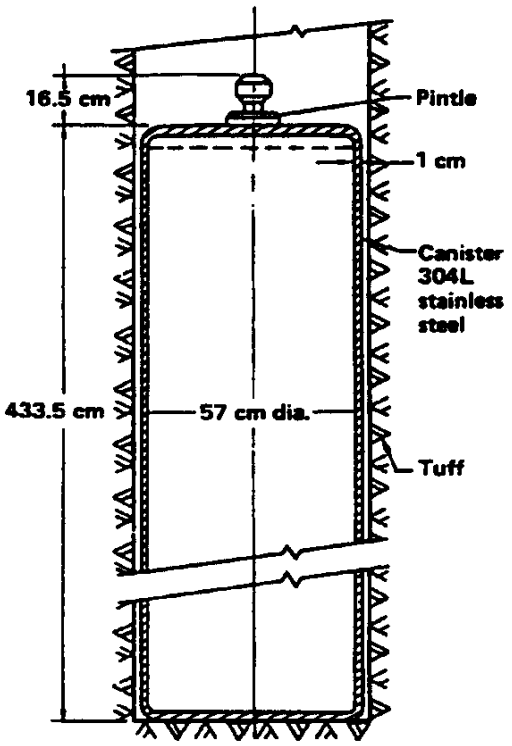

Figure 8. Reference Spent Fuel Waste Package

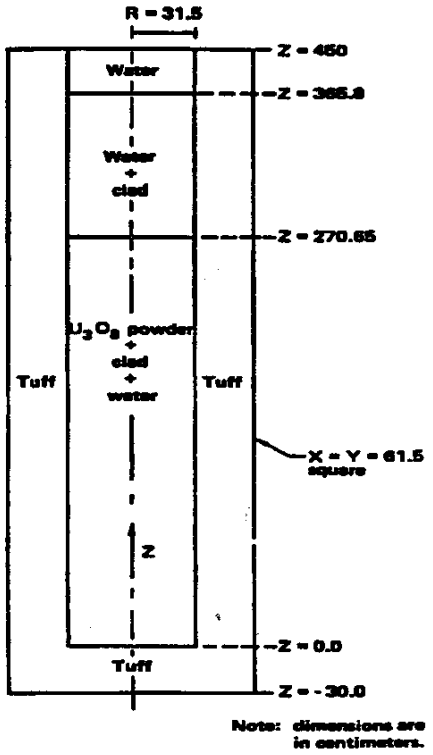

Figure 9. KENO Geometry for Configuration 10

arrive at the total of seven calculations. The geometry of Configuration 10 is shown in Figure 9. The results of the seven calculations are shown in Table 7.

Table 7

K_{eff} Calculations from Reference 11

Configuration	Fuel Enrichment (%)	k_{eff}	Total Uncertainity
1	4.5	0.371	0.015
2	4.5	0.685	0.017
6	4.5	1.179	0.016
6	2.0	0.998	0.021
6	1.0	0.788	0.020
10	4.5	1.160	0.015
10	1.6	0.952	0.019

7.1.3 Conclusions Concerning Commercial Fuel

For many configurations of fuel, container, and canister, criticality would be a distinct possibility. One can get into long discussions about limiting the amount of material per container, about adding neutron poisons, or about taking credit for burnup, etc. There are problems with all the solutions. Limiting the mass per canister is expensive. The problem with neutron poisons is ensuring that they stay with the fuel. Taking credit for burnup requires foolproof administrative controls. The fact that no decisions have been reached concerning the criticality issue is indicative of this situation.

One certainty does exist in this area. Highly enriched uranium fuels will have a criticality problem that dwarfs the commercial fuel problem. As will be seen in the following section, technical fixes can be applied but they will be

expensive. Whatever savings that may be realized from stopping reprocessing may be offset by the costs of dealing with the criticality issue of direct disposal.

7.2 ICPP Proposed Solutions for Defense Fuel

As shown in Tables 3 through 6, there are numerous forms of irradiated fuel that would be candidates for direct disposal. The details of waste packages for each type of fuel would necessarily be different. However, in the main, the options that one could choose to deal with the criticality threat for each fuel type are quite similar and more or less independent of the specific fuel type details.

7.2.1 Waste Package Options and Risks from Unpoisoned Fuel—Direct Disposal of Naval Fuel

The naval fuel assemblies are clad such that if plates were welded on the ends of the assembly, the cladding would provide a robust engineered barrier to fission product and actinide release, probably as good as the current canister design for commercial fuel. The discussed loading level is three assemblies in a waste canister per repository borehole. The assemblies would be welded end-to-end, thus presenting a thin, pencil shape, only one assembly wide in cross section. To obtain a criticality event, water must enter the borehole and the welds must break down to allow the assemblies to rearrange to a more reactive side-by-side arrangement. This is an example of the two-barrier approach to criticality prevention.

ICPP considers the risk of a criticality event over one million or so years for such an assemblage to be high.[3] An earthquake is envisaged as capable of causing flooding and reconfiguration of the three assembly canister into a critical state. Only a low rate of travel of fission products could prevent contamination of the groundwater supplies, but a large earthquake is likely to provide rapid pathways to the surface.

Poisoned Fuel

This option would be performed by inserting neutron poison elements into the fuel coolant channels of the fuel. The three assemblies would then be welded into the pencil shape with welded on end plates. The canister with the three assemblies inserted would be filled with molten copper to enhance its physical integrity.

ICPP considers the criticality risk for this arrangement to be low.[3] It is not zero because the earthquake could again break down the assemblies into a side-by-side configuration. Prolonged exposure to water could leach out the poisons. Clearly, the copper strengthener would work to prevent these untoward events, but there is no assurance that they could not occur over geologic time periods.

Diluted Fuel

In this option, the naval fuel would be dissolved and mixed with depleted uranium and perhaps other low-enriched fuel to obtain a mixture with an enrichment of 0.7% or less, the same as for natural uranium. The liquid mixture would then be contained and converted to a ceramic-glass form and placed in a waste canister.

The risk of criticality for this wasteform is the same as for any other natural uranium ore pocket, near zero but not truly zero.[3] Nevertheless, it is difficult to imagine this solution not being acceptable to regulators as a solution to the criticality problem. The number of spent fuel canisters created for ICPP inventories is given in Table 8 for each of the three criticality control measures.

7.2.2 Waste Package Costs

ICPP made cost estimates for each of these options in terms of Operating Expense, Capital Costs, and Canister Costs. The results of their analysis appeared in Table S-3. The assumptions for these cost estimates are reproduced below.[3] Assumptions pertaining only to reprocessing options (also studied by ICPP) have been deleted from the following list.

1. The study period was set from FY 1991-2038 (48 years) to help assure a representative life cycle for each case (i.e., facility replacement and "Complex 21" issues would be reflected).
2. Fuel receipts are specified in the DOE-HQ Long-Range Fuel Receipt Forecasts. Ending inventories of fuel stored in basins is [sic] the same in all cases.

Table 8

Canister Production Required to Dispose of Spent Fuel at ICPP*

	Number of Canisters
Unpoisoned Fuel	8,939
Poisoned Fuel	7,526
Diluted Fuel	12,390

* A further breakdown of the chemical and/or mechanical processes required to construct the canisters is given in Reference 3 (Table 4-2).

Thus, equivalent quantities of fuel are dispositioned in each scenario and resources to assure continued fuel receipt are assumed to be made available in a timely manner.

3. All applicable ES&H requirements are to be met in all cases.
4. Costs in the analyses are in FY 1991 dollars in 1991, 1992 dollars for FY 1992, and beyond.
5. Cost estimates for fuel reprocessing are based on annual operating costs, FY 1992 budget submission, and current multi-annual budget requests.
6. A $400,000/canister cost is used for transportation and storage in a federal repository. This cost is used for both immobilized waste and fuel canisters. This is based on the Federal Register for two repositories adding escalation and adjustments to arrive at FY 1992 dollars. Formulas for charges equivalent to commercial fee do not yet exist but are expected to exceed this value.
7. Repository costs are incurred in the year the canisters are shipped.
8. A commercial fuel canister is used for disposal of waste and fuel. The canisters are 26″ in diameter and 15′ long. This is about twice the size of a DWPF (Defense Waste Processing Facility) canister.
9. The decontamination and decommissioning (D&D) costs for the cases will be approximately equal since the overall number of facilities to be decontaminated is about the same. (However, the implementation of the D&D program would occur much sooner for the direct disposal cases and the funding for this program could be great enough to be a discriminatory issue. No estimates for D&D costs were used, since the speculative nature of these costs was considered to be too great.)
10. To bound cost differences, it is assumed that the federal repository will be available for receipt of immobilized ICPP fuel in FY 2012 and immobilized waste in FY 2014. (The immobilized waste generated during the period will most likely go into the second federal repository in 2040. The repository at Yucca Mountain is scheduled to begin operation in 2010. Space has been allocated for 17,750 canisters of defense waste. Those wastes will come from SRS, WVDP, Hanford, and ICPP, which will have 8840 canister positions. The possibility is considered that the first repository will fill with other defense waste before ICPP immobilized fuel or waste is ready to ship.)
11. RCRA permitting will be obtained in a timely manner for all wasteforms.
12. Required capital funding for projects needed to meet ES&H requirements are completed.

7.3 NPR Proposed Solutions

The NPR Group at SRS proposed solutions for the criticality problem, posed by direct disposal of NPR-HWR fuel, that are quite similar to those proposed by ICPP for their fuel.[8,10]

Table 9
Geologic Disposal Lifecycle Cost

	Lwr Plant (1,000 MWe)	100% HWR Base Case (Normal-Burn)	31% HWR Option G (Deep-Burn)
Basis	1 mil/KWeHr	Planning Est	Planning Est
No. Spent Fuel Assemblies	2,400	29,120	4,160
Life cycle Cost*, 1990 $M	270	2,909	719
Unit Cost*, $M/canister	0.56 canister	0.60	1.04

*Does not include life cycle cost for interim water pool storage facility for LWR and HWR plants.

One of the NPR options involved chemical partitioning of the HEU. That option will not be included in this discussion but was summarized in the Summary. The remaining three options were:

1. Unpoisoned Fuel—Use a low number of unpoisoned fuel assemblies (2) per canister, spaced sufficiently widely in the repository to assure no concentrations permitting criticality.
2. Poisoned Fuel—Use up to 6 (typically) fuel assemblies per container with nuclear poisons to prevent criticality.
3. Diluted Fuel—Melt the fuel of up to 30 spent fuel assemblies and mix in depleted uranium to an isotopic concentration approximating natural uranium.

The following facilities would be needed:

- discharged fuel pool for cooling the assemblies for 5-10 years
- intermediate dry-term storage pending availability of a second repository
- packaging facility for repository
- transport facilities.

Reference 10 implicitly assumes that the last two facilities would be charged against the NPR. A more likely assumption is that these facilities would be common to all users of the second repository.

None of the NPR studies attempted to estimate the criticality risk associated with the spent fuel. In principle, the qualitative estimates should be about the same as were made by ICPP for their spent fuels, except that the unpoisoned NPR fuel risk should be near zero, not high, when a mass limitation per canister is imposed.

The number of spent fuel assemblies, and, hence, the costs for disposal, depends on the size of the NPR. Table 9 compares two options to a typical 1,000 MW$_e$LWR. Nine different point reactor designs were costed in terms of the interim storage cost, spent fuel conditioning costs, transportation costs, and repository fees. Aside from the size of the reactor, the costs are affected mainly by the length of the reactor irradiation. In Table 10, the spent fuel costs for eight designs (A-H) are given for both a low-burn (1 fuel batch) and a deep-burn (2 fuel batches) cycle.

8. Safeguards

Commercial reactor fuels are limited to enrichments of less than 5% U-235. However, some HEU spent fuels have enrichments that could range up to >90% following low exposure irradiations. This raises the safeguards issue for the geologic repository and any monitored retrievable storage facilities that might be constructed for HEU spent fuels.

The applicable NRC regulation in 10 CFR Part 60 states that information should be supplied in the license application that includes:

- A certification that DOE will provide at the geologic repository operations area such safeguards as it requires at comparable surface facilities (of DOE) to promote the common defense and security.
- A description of the physical security plan for protection against radiological sabotage. Since the radiation hazards associated with high-level wastes make them inherently unattractive as a target for theft or diversion, no detailed information need be submitted on protection against theft and diversion.

Table 10
Total Life Cycle Costs, Year 1990 Constant $M[a]

HWR Point Design	Unpoisoned Canister (Flowsheet 1)	Poisoned Canister (Flowsheet 2)	Diluted w/U-238 in Unpoisoned Canister (Flowsheet 3)
100% HWR (Base Case)			
1-Batch	7,981	4,556	3,166
2-Batch	4,807	2,823	2,233
50% HWR (Option A)			
1-Batch	3,842	2,292	1,915
2-Batch	2,318	1,485	1,440
50% HWR (Option B)			
1-Batch	3,842	2,292	1,915
2-Batch	2,318	1,485	1,440
25% HWR 1-C (Option C)			
1-Batch	4,012	2,383	1,968
2-Batch	1,699	1,154	1,235
25% HWR (Option D)			
1-Batch	2,955	1,816	1,632
2-Batch	1,791	1,192	1,251
2 × 25% HWRs (Option E)			
1-Batch	6,768	3,882	2,809
2-Batch	2,813	1,776	1,639
37.5% HWR (Option F)			
1-Batch	4,012	2,383	1,968
2-Batch	2,213	1,430	1,408
31% HWR (Option G)			
1-Batch	4,599	2,698	2,149
2-Batch	1,929	1,284	1,322
37.5% HWR (Option G-Sprint)			
1-Batch	na	na	na
2-Batch	2,022	1,354	1,380

In the Construction Authorization section of 10 CFR Part 60, NRC will authorize construction of the repository if it determines (among other items)...

- That there is reasonable assurance that the activities proposed in the application will not be inimical to the common defense and security. A DOE certification that it will provide at the geologic repository operations area such safeguards as it requires at comparable DOE surface facilities will constitute a rebuttable presumption of noninimicality to the common defense and security.

Exactly the same wording appears in the section entitled "License Issuance and Amendment".

The implication of the above requirements is that DOE must provide safeguards to the repository, at least during the first 50 years of operation. No requirement to provide safeguards specifically during the post-closure period appears in 10 CFR Part 60. The statement that theft and diversion need not be protected against implies that buried spent fuel is not considered a viable source of U-235 for non-weapons states or terrorist organizations.

One should bear in mind that 10 CFR Part 60 was written in connection with the Nuclear Waste Policy Act of 1982, which specifically restricted the first repository to defense HLW (containing little, if any, fissile material) and to spent commercial fuels (with <5% U-235). Under these conditions, it would appear reasonable to argue that the spent fuel need not be safeguarded in perpetuity.

However, if a second repository were built and HEU fuels were entombed in it, the fuels could, in time, become reasonably attractive targets for diversion. After about 300 years to 1,000 years, the fission product activity would, in the main, have disappeared. Only the minor actinides would still provide activity and it is not clear at this point that such activity would be sufficient to discourage diversion attempts.

Admittedly, the guarding of the fuel need only be minimal. The guards would need only to look for signs of tunneling. Diversion would take such a long time that the risk of detection would be extremely high. Nevertheless, it seems that some form of a guard force would have to be provided in perpetuity for the second repository if it contained HEU spent fuels.

The above analysis does not reach an unambiguous conclusion. Moreover, it is not clear that such a conclusion can be reached on the basis of technical considerations alone. The need for safeguards for a repository containing HEU spent fuels threatens to become a contentious issue that could embroil the second repository in political controversy.

9. Classification

The classification issue affects the different site fuels in various ways, ranging from no application for commercial spent fuels to a significant issue for naval fuel.

Commercial Fuel

Most aspects of the commercial nuclear power program are completely unclassified. In particular, the details of the fuel geometries and irradiation histories are unclassified. The repository will need this detailed information, primarily to ensure that criticality safe limits are not exceeded at any step of the fuel disposal process.

Defense Production Fuels at SRS

At SRS, all topics of HEU fuel tube composition (before and after irradiation) are normally Unclassified or Unclassified Nuclear Information (UCNI). This includes such details as:

- U-235 content
- shapes and dimensions
- other uranium isotopic content
- minor actinide isotopic content
- fission product content
- irradiation history (power levels and exposure)
- shapes and dimensions.

However, when such fuel is being transported from one safeguarded facility to another, all of these fuel details are classified Confidential National Security Information (CNSI).

No decisions have yet been rendered on the classification to be applied at the second repository on defense production spent fuel details. If the facility has safeguards, the details are likely to be unclassified once the fuel has arrived. Without safeguards, classification could be imposed. Distinctions may be necessary for pre-closure and post-closure conditions.

The rules already established for the Yucca Mountain Repository have the spent fuel details treated as unclassified. However, this should not be interpreted as the probable finding for the second repository.

Naval Fuel

The details of naval fuels are highly classified, even after the irradiation in the naval propulsion reactors. Thus, certain people involved with the disposal of naval fuel at the second repository will have to be cleared to the appropriate Navy levels. Transmission of such information to licensing authorities, oversight groups (state and federal), and to outside intervenors will have to be carefully regulated. Similar problems have arisen in other programs, and the administrative costs of providing an administrative solution to the naval fuel problem can probably be estimated on the basis of these other program experiences.

Special Fuels

Some of the special fuels may have been associated with classified programs and may have restrictions, similar to those for naval fuel, on the needed details. (This is speculation on the author's part.) If so, appropriate classification would need to be applied at the second repository.

Summary

Classification is not likely to become a contentious issue for the second repository. There will be an administrative cost for the adopted classification systems that will have to be taken into account for the estimations of the second repository costs.

10. DOE Policies Pertinent to Direct Disposal of HEU Fuels

In April 1991, the Secretary of Energy directed the Under Secretary to chair a task force to recommend future DOE policy regarding HEU. In June of 1991, that Task Force recommended that DOE cease production of HEU at the Portsmouth Gaseous Diffusion Plant. Sufficient stocks of HEU were identified to meet all defense needs, including a strategic reserve, well into the next century. That policy has since been put into effect.

At that time, the Task Force had not completed its examination of the questions concerning reprocessing of defense fuels and naval fuels to recover the unburned HEU. By spring of 1992, those studies were completed and the following actions were undertaken:[15]

- Reprocessing at ICPP was to be curtailed immediately beginning with an orderly deactivation of the reprocessing facilities. Reprocessing at Hanford had already been curtailed in 1990-91. Both the Hanford and ICPP reprocessing facilities were to be turned over to DOE-EM.

- Reprocessing at SRS was to be continued until the 1996-97 time frame, but only for the purpose of processing the existing liquid actinide stocks (Pu, Pu-238, Np-237, Pu-242) and for the purpose of processing the existing fuels and targets in the P-, K- and L-Area disassembly basins and RBOF (aluminum-clad fuels only).

The present Program Execution Guidance from DOE puts these recommendations into effect.

Long-term decisions on the matter of spent fuel management will constitute a major Federal Action as defined by NEPA. Preparation of an Environmental Impact Statement (EIS) with an attendant Record of Decision (ROD) was recommended at the secretarial level but the outcome of these deliberations is unknown to the author.[15] It was further recommended that DOE-EM be given the responsibility for preparing the EIS and gathering information to support the ROD. In the meantime, the recommendations envisaged ownership of the spent fuel and reprocessing facilities passing from DOE-DP to DOE-EM as rapidly as possible.[15]

Long-term decisions on the disposition of spent fuel will have to await guidance from the current programs concerning commercial spent fuel to be disposed of in the geologic waste repository at Yucca Mountain. The principal issue to be decided here is the criticality issue. The adequacy of any particular strategy adopted for Yucca Mountain by DOE-RW will not be tested until the licensing process begins (~ 2001-2007). At that time, NRC will decide the issue.

DOE-EM believes strongly that the existing reprocessing facilities will not be used, even if continued reprocessing of the spent fuel proves to be necessary by virtue of the failure

of a direct disposal policy in the future.[15] In effect, DOE-EM is counting on being able to build new reprocessing facilities as part of Complex 21, if needed. However, it should be noted that no reprocessing facilities are included in the present Complex 21 planning.

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Appendix A

SUBCHAPTER F—RADIATION PROTECTION PROGRAMS

PART 190—ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NUCLEAR POWER OPERATIONS

Subpart A—General Provisions

Sec.
190.01 Applicability.
190.02 Definitions.

Subpart B—Environmental Standards for the Uranium Fuel Cycle

190.10 Standards for normal operations.
190.11 Variances for unusual operations.
190.12 Effective date.

AUTHORITY: Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3, of 1970.

SOURCE: 42 FR 2860, Jan. 13, 1977, unless otherwise noted.

Subpart A—General Provisions

§ 190.01 Applicability.

The provisions of this part apply to radiation doses received by members of the public in the general environment and to radioactive materials introduced into the general environment as the result of operations which are part of a nuclear fuel cycle.

§ 190.02 Definitions.

(a) *Nuclear fuel cycle* means the operations defined to be associated with the production of electrical power for public use by any fuel cycle through utilization of nuclear energy.

(b) *Uranium fuel cycle* means the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel, to the extent that these directly support the production of electrical power for public use utilizing nuclear energy, but excludes mining operations, operations at waste disposal sites, transportation of any radioactive material in support of these operations, and the reuse of recovered nonuranium special nuclear and by-product materials from the cycle.

(c) *General environment* means the total terrestrial, atmospheric and aquatic environments outside sites upon which any operation which is part of a nuclear fuel cycle is conducted.

(d) *Site* means the area contained within the boundary of a location under the control of persons possessing or using radioactive material on which is conducted one or more operations covered by this part.

(e) *Radiation* means any or all of the following: Alpha, beta, gamma, or X-rays; neutrons; and high-energy electrons, protons, or other atomic particles; but not sound or radio waves, nor visible, infrared, or ultraviolet light.

(f) *Radioactive material* means any material which spontaneously emits radiation.

(g) *Curie* (Ci) means that quantity of radioactive material producing 37 billion nuclear transformations per second. (One millicurie (mCi)=0.001 Ci.)

(h) *Dose equivalent* means the product of absorbed dose and appropriate factors to account for differences in biological effectiveness due to the quality of radiation and its spatial distribution in the body. The unit of dose equivalent is the "rem." (One millirem (mrem)= 0.001 rem.)

(i) *Organ* means any human organ exclusive of the dermis, the epidermis, or the cornea.

(j) *Gigawatt-year* refers to the quantity of electrical energy produced at the busbar of a generating station. A gigawatt is equal to one billion watts. A gigawatt-year is equivalent to the amount of energy output represented by an average electric power level of one gigawatt sustained for one year.

(k) *Member of the public* means any individual that can receive a radiation dose in the general environment, whether he may or may not also be exposed to radiation in an occupation associated with a nuclear fuel cycle. However, an individual is not considered a member of the public during

any period in which he is engaged in carrying out any operation which is part of a nuclear fuel cycle.

(l) *Regulatory agency* means the government agency responsible for issuing regulations governing the use of sources of radiation or radioactive materials or emissions therefrom and carrying out inspection and enforcement activities to assure compliance with such regulations.

Subpart B—Environmental Standards for the Uranium Fuel Cycle

§ 190.10 Standards for normal operations.

Operations covered by this subpart shall be conducted in such a manner as to provide reasonable assurance that:

(a) The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations.

(b) The total quantity of radioactive materials entering the general environment from the entire uranium fuel cycle, per gigawatt-year of electrical energy produced by the fuel cycle, contains less than 50,000 curies of krypton-85, 5 millicuries of iodine-129, and 0.5 millicuries combined of plutonium-239 and other alpha-emitting transuranic radionuclides with half-lives greater than one year.

§ 190.11 Variances for unusual operations.

The standards specified in § 190.10 may be exceeded if:

(a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is in the public interest, and

(b) Information is promptly made a matter of public record delineating the nature of unusual operating conditions, the degree to which this operation is expected to result in levels in excess of the standards, the basis of the variance, and the schedule for achieving conformance with the standards.

§ 190.12 Effective date.

(a) The standards in § 190.10(a) shall be effective December 1, 1979, except that for doses arising from operations associated with the milling of uranium ore the effective date shall be December 1, 1980.

(b) The standards in § 190.10(b) shall be effective December 1, 1979, except that the standards for krypton-85 and iodine-129 shall be effective January 1, 1983, for any such radioactive materials generated by the fission process after these dates.

PART 191—ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR MANAGEMENT AND DISPOSAL OF SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

Subpart A—Environmental Standards for Management and Storage

Sec.

Subpart B—Environmental Standards for Disposal

AUTHORITY: The Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act of 1982.

SOURCE: 50 FR 38084, Sept. 19, 1985, unless otherwise noted.

Subpart A—Environmental Standards for Management and Storage

§ 191.01 Applicability.

This subpart applies to:

(a) Radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at any facility regulated by the Nuclear Regulatory Commission or by Agreement States, to the extent that such management and storage operations are not subject to the provisions of Part 190 of Title 40; and

(b) Radiation doses received by members of the public as a result of the management and storage of spent nuclear fuel or high-level or transuranic wastes at any disposal facility that is operated by the Department of Energy and that is not regulated by the Commission or by Agreement States.

§ 191.02 Definitions.

Unless otherwise indicated in this subpart, all terms shall have the same meaning as in Subpart A of Part 190.

(a) *Agency* means the Environmental Protection Agency.

(b) *Administrator* means the Administrator of the Environmental Protection Agency.

(c) *Commission* means the Nuclear Regulatory Commission.

(d) *Department* means the Department of Energy.

(e) *NWPA* means the Nuclear Waste Policy Act of 1982 (Pub. L. 97-425).

(f) *Agreement State* means any State with which the Commission or the Atomic Energy Commission has entered into an effective agreement under subsection 274b of the Atomic Energy Act of 1954, as amended (68 Stat. 919).

(g) *Spent nuclear fuel* means fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

(h) *High-level radioactive waste*, as used in this part, means high-level radioactive waste as defined in the Nuclear Waste Policy Act of 1982 (Pub. L. 97-425).

(i) *Transuranic radioactive waste*, as used in this part, means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than twenty years, per gram of waste, except for: (1) High-level radioactive wastes; (2) wastes that the Department has determined, with the concurrence of the Administrator, do not need the degree of isolation required by this part; or (3) wastes that the Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.

(j) *Radioactive waste*, as used in this part, means the high-level and transuranic radioactive waste covered by this part.

(k) *Storage* means retention of spent nuclear fuel or radioactive wastes with the intent and capability to readily retrieve such fuel or waste for subsequent use, processing, or disposal.

(l) *Disposal* means permanent isolation of spent nuclear fuel or radioactive waste from the accessible environment with no intent of recovery, whether or not such isolation permits the recovery of such fuel or waste. For example, disposal of waste in a mined geologic repository occurs when all of the shafts to the repository are backfilled and sealed.

(m) *Management* means any activity, operation, or process (except for transportation) conducted to prepare spent nuclear fuel or radioactive waste for storage or disposal, or the activities associated with placing such fuel or waste in a disposal system.

(n) *Site* means an area contained within the boundary of a location under the effective control of persons possessing or using spent nuclear fuel or radioactive waste that are involved in any activity, operation, or process covered by this subpart.

(o) *General environment* means the total terrestrial, atmospheric, and aquatic environments outside sites within which any activity, operation, or process associated with the management and storage of spent nuclear fuel or radioactive waste is conducted.

(p) *Member of the public* means any individual except during the time when that individual is a worker engaged in any activity, operation, or

process that is covered by the Atomic Energy Act of 1954, as amended.

(q) *Critical organ* means the most exposed human organ or tissue exclusive of the integumentary system (skin) and the cornea.

§ 191.03 Standards.

(a) Management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities regulated by the Commission or by Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from: (1) Discharges of radioactive material and direct radiation from such management and storage and (2) all operations covered by Part 190; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other critical organ.

(b) Management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the Department and that are not regulated by the Commission or Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.

§ 191.04 Alternative standards.

(a) The Administrator may issue alternative standards from those standards established in § 191.03(b) for waste management and storage activities at facilities that are not regulated by the Commission or Agreement States if, upon review of an application for such alternative standards:

(1) The Administrator determines that such alternative standards will prevent any member of the public from receiving a continuous exposure of more than 100 millirems per year dose equivalent and an infrequent exposure of more than 500 millirems dose equivalent in a year from all sources, excluding natural background and medical procedures; and

(2) The Administrator promptly makes a matter of public record the degree to which continued operation of the facility is expected to result in levels in excess of the standards specified in § 191.03(b).

(b) An application for alternative standards shall be submitted as soon as possible after the Department determines that continued operation of a facility will exceed the levels specified in § 191.03(b) and shall include all information necessary for the Administrator to make the determinations called for in § 191.04(a).

(c) Requests for alternative standards shall be submitted to the Administrator, U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460.

§ 191.05 Effective date.

The standards in this subpart shall be effective on November 18, 1985.

Subpart B—Environmental Standards for Disposal

§ 191.11 Applicability.

(a) This subpart applies to:

(1) Radioactive materials released into the accessible environment as a result of the disposal of spent nuclear fuel or high-level or transuranic radioactive wastes;

(2) Radiation doses received by members of the public as a result of such disposal; and

(3) Radioactive contamination of certain sources of ground water in the vicinity of disposal systems for such fuel or wastes.

(b) However, this subpart does not apply to disposal directly into the oceans or ocean sediments. This subpart also does not apply to wastes disposed of before the effective date of this rule.

§ 191.12 Definitions.

Unless otherwise indicated in this subpart, all terms shall have the same meaning as in Subpart A of this part.

(a) *Disposal system* means any combination of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal.

(b) *Waste,* as used in this subpart, means any spent nuclear fuel or radioactive waste isolated in a disposal system.

(c) *Waste form* means the materials comprising the radioactive components of waste and any encapsulating or stabilizing matrix.

(d) *Barrier* means any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment. For example, a barrier may be a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides.

(e) *Passive institutional control* means: (1) Permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system.

(f) *Active institutional control* means: (1) Controlling access to a disposal site by any means other than passive institutional controls; (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance.

(g) *Controlled area* means: (1) A surface location, to be identified by passive institutional controls, that encompasses no more than 100 square kilometers and extends horizontally no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system; and (2) the subsurface underlying such a surface location.

(h) *Ground water* means water below the land surface in a zone of saturation.

(i) *Aquifer* means an underground geological formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring.

(j) *Lithosphere* means the solid part of the Earth below the surface, including any ground water contained within it.

(k) *Accessible environment* means: (1) The atmosphere; (2) land surfaces; (3) surface waters; (4) oceans; and (5) all of the lithosphere that is beyond the controlled area.

(l) *Transmissivity* means the hydraulic conductivity integrated over the saturated thickness of an underground formation. The transmissivity of a series of formations is the sum of the individual transmissivities of each formation comprising the series.

(m) *Community water system* means a system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

(n) *Significant source of ground water,* as used in this part, means: (1) An aquifer that: (i) Is saturated with water having less than 10,000 milligrams per liter of total dissolved solids; (ii) is within 2,500 feet of the land surface; (iii) has a transmissivity greater than 200 gallons per day per foot, *Provided,* That any formation or part of a formation included within the source of ground water has a hydraulic conductivity greater than 2 gallons per day per square foot; and (iv) is capable of continuously yielding at least 10,000 gallons per day to a pumped or flowing well for a period of at least a year; or (2) an aquifer that provides the primary source of water for a community water system as of the effective date of this subpart.

(o) *Special source of ground water,* as used in this part, means those Class I ground waters identified in accordance with the Agency's Ground-Water Protection Strategy published in August 1984 that: (1) Are within the controlled area encompassing a disposal system or are less than five kilometers beyond the controlled area; (2) are supplying drinking water for thousands of persons as of the date that the Department chooses a location within that area for detailed charac-

terization as a potential site for a disposal system (e.g., in accordance with section 112(b)(1)(B) of the NWPA); and (3) are irreplaceable in that no reasonable alternative source of drinking water is available to that population.

(p) *Undisturbed performance* means the predicted behavior of a disposal system, including consideration of the uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events.

(q) *Performance assessment* means an analysis that: (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. These estimates shall be incorporated into an overall probability distribution of cumulative release to the extent practicable.

(r) *Heavy metal* means all uranium, plutonium, or thorium placed into a nuclear reactor.

(s) *Implementing agency*, as used in this subpart, means the Commission for spent nuclear fuel or high-level or transuranic wastes to be disposed of in facilities licensed by the Commission in accordance with the Energy Reorganization Act of 1974 and the Nuclear Waste Policy Act of 1982, and it means the Department for all other radioactive wastes covered by this part.

§ 191.13 Containment requirements.

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall:

(1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

(2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A).

(b) Performance assessments need not provide complete assurance that the requirements of § 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with § 191.13 (a) will be achieved.

§ 191.14 Assurance requirements.

To provide the confidence needed for long-term compliance with the requirements of § 191.13, disposal of spent nuclear fuel or high-level or transuranic wastes shall be conducted in accordance with the following provisions, except that these provisions do not apply to facilities regulated by the Commission (see 10 CFR Part 60 for comparable provisions applicable to facilities regulated by the Commission):

(a) Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.

(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.

(c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location.

public hearings in affected areas of the country has been provided; and

(c) The public comments received have been fully considered in developing the final version of such alternative provisions.

§ 191.18 Effective date.

The standards in this subpart shall be effective on November 18, 1985.

[50 FR 38084, Sept. 19, 1985; 50 FR 40003, Oct. 1, 1985]

Appendix A—Table for Subpart B

TABLE 1—RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS

(Cumulative releases to the accessible environment for 10,000 years after disposal)

Radionuclide	Release limit per 1,000 MTHM or other unit of waste (see notes) (curies)
Americium-241 or -243	100
Carbon-14	100
Cesium-135 or -137	1,000
Iodine-129	100
Neptunium-237	100
Plutonium-238, -239, -240, or -242	100
Radium-226	100
Strontium-90	1,000
Technetium-99	10,000
Thorium-230 or -232	10
Tin-126	1,000
Uranium-233, -234, -235, -236, or -238	100
Any other alpha-emitting radionuclide with a half-life greater than 20 years	100
Any other radionuclide with a half-life greater than 20 years that does not emit alpha particles	1,000

Application of Table 1

Note 1: *Units of Waste.* The Release Limits in Table 1 apply to the amount of wastes in any one of the following:

(a) An amount of spent nuclear fuel containing 1,000 metric tons of heavy metal (MTHM) exposed to a burnup between 25,000 megawatt-days per metric ton of heavy metal (MWd/MTHM) and 40,000 MWd/MTHM;

(b) The high-level radioactive wastes generated from reprocessing each 1,000 MTHM exposed to a burnup between 25,000 MWd/MTHM and 40,000 MWd/MTHM;

(c) Each 100,000,000 curies of gamma or beta-emitting radionuclides with half-lives greater than 20 years but less than 100 years (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA);

(d) Each 1,000,000 curies of other radionuclides (i.e., gamma or beta-emitters with half-lives greater than 100 years or any alpha-emitters with half-lives greater than 20 years) (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA); or

(e) An amount of transuranic (TRU) wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years.

Note 2: *Release Limits for Specific Disposal Systems.* To develop Release Limits for a particular disposal system, the quantities in Table 1 shall be adjusted for the amount of waste included in the disposal system compared to the various units of waste defined in Note 1. For example:

(a) If a particular disposal system contained the high-level wastes from 50,000 MTHM, the Release Limits for that system would be the quantities in Table 1 multiplied by 50 (50,000 MTHM divided by 1,000 MTHM).

(b) If a particular disposal system contained three million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by three (three million curies divided by one million curies).

(c) If a particular disposal system contained both the high-level wastes from 50,000 MTHM *and* 5 million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by 55:

$$\frac{50{,}000\ \text{MTHM}}{1{,}000\ \text{MTHM}} + \frac{5{,}000{,}000\ \text{curies TRU}}{1{,}000{,}000\ \text{curies TRU}} = 55$$

Note 3: *Adjustments for Reactor Fuels with Different Burnup.* For disposal systems containing reactor fuels (or the high-level wastes from reactor fuels) exposed to an average burnup of less than 25,000 MWd/MTHM or greater than 40,000 MWd/MTHM, the units of waste defined in (a) and (b) of Note 1 shall be adjusted. The unit shall be multiplied by the ratio of 30,000 MWd/MTHM divided by the fuel's actual average burnup, except that a value of 5,000 MWd/MTHM may be used when the average fuel burnup is below 5,000 MWd/MTHM and a value of 100,000 MWd/MTHM shall be used when the average fuel

burnup is above 100,000 MWd/MTHM. This adjusted unit of waste shall then be used in determining the Release Limits for the disposal system.

For example, if a particular disposal system contained only high-level wastes with an average burnup of 3,000 MWd/MTHM, the unit of waste for that disposal system would be:

$$1{,}000\ \text{MTHM} \times \frac{(30{,}000)}{(5{,}000)} = 6{,}000\ \text{MTHM}$$

If that disposal system contained the high-level wastes from 60,000 MTHM (with an average burnup of 3,000 MWd/MTHM), then the Release Limits for that system would be the quantities in Table 1 multiplied by ten:

$$\frac{60{,}000\ \text{MTHM}}{6{,}000\ \text{MTHM}} = 10$$

which is the same as:

$$\frac{60{,}000\ \text{MTHM}}{1{,}000\ \text{MTHM}} \times \frac{(5{,}000\ \text{MWd/MTHM})}{(30{,}000\ \text{MWd/MTHM})} = 10$$

NOTE 4: *Treatment of Fractionated High-Level Wastes.* In some cases, a high-level waste stream from reprocessing spent nuclear fuel may have been (or will be) separated into two or more high-level waste components destined for different disposal systems. In such cases, the implementing agency may allocate the Release Limit multiplier (based upon the original MTHM and the average fuel burnup of the high-level waste stream) among the various disposal systems as it chooses, provided that the total Release Limit multiplier used for that waste stream at all of its disposal systems may not exceed the Release Limit multiplier that would be used if the entire waste stream were disposed of in one disposal system.

NOTE 5: *Treatment of Wastes with Poorly Known Burnups or Original MTHM.* In some cases, the records associated with particular high-level waste streams may not be adequate to accurately determine the original metric tons of heavy metal in the reactor fuel that created the waste, or to determine the average burnup that the fuel was exposed to. If the uncertainties are such that the original amount of heavy metal or the average fuel burnup for particular high-level waste streams cannot be quantified, the units of waste derived from (a) and (b) of Note 1 shall no longer be used. Instead, the units of waste defined in (c) and (d) of Note 1 shall be used for such high-level waste streams. If the uncertainties in such information allow a range of values to be associated with the original amount of heavy metal or the average fuel burnup, then the calculations described in previous Notes will be conducted using the values that result in the smallest Release Limits, except that the Release Limits need not be smaller than those that would be calculated using the units of waste defined in (c) and (d) of Note 1.

NOTE 6: *Uses of Release Limits to Determine Compliance with § 191.13* Once release limits for a particular disposal system have been determined in accordance with Notes 1 through 5, these release limits shall be used to determine compliance with the requirements of § 191.13 as follows. In cases where a mixture of radionuclides is projected to be released to the accessible environment, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 1 and Notes 1 through 5. The sum of such ratios for all the radionuclides in the mixture may not exceed one with regard to § 191.13(a)(1) and may not exceed ten with regard to § 191.13(a)(2).

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, and RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} \leq 1.$$

APPENDIX B—GUIDANCE FOR IMPLEMENTATION OF SUBPART B

[NOTE: The supplemental information in this appendix is not an integral part of 40 CFR Part 191. Therefore, the implementing agencies are not bound to follow this guidance. However, it is included because it de-

scribes the Agency's assumptions regarding the implementation of Subpart B. This appendix will appear in the Code of Federal Regulations.]

The Agency believes that the implementing agencies must determine compliance with §§ 191.13, 191.15, and 191.16 of Subpart B by evaluating long-term predictions of disposal system performance. Determining compliance with § 191.13 will also involve predicting the likelihood of events and processes that may disturb the disposal system. In making these various predictions, it will be appropriate for the implementing agencies to make use of rather complex computational models, analytical theories, and prevalent expert judgment relevant to the numerical predictions. Substantial uncertainties are likely to be encountered in making these predictions. In fact, sole reliance on these numerical predictions to determine compliance may not be appropriate; the implementing agencies may choose to supplement such predictions with qualitative judgments as well. Because the procedures for determining compliance with Subpart B have not been formulated and tested yet, this appendix to the rule indicates the Agency's assumptions regarding certain issues that may arise when implementing §§ 191.13, 191.15, and 191.16. Most of this guidance applies to any type of disposal system for the wastes covered by this rule. However, several sections apply only to disposal in mined geologic repositories and would be inappropriate for other types of disposal systems.

Consideration of Total Disposal System. When predicting disposal system performance, the Agency assumes that reasonable projections of the protection expected from all of the engineered and natural barriers of a disposal system will be considered. Portions of the disposal system should not be disregarded, even if projected performance is uncertain, except for portions of the system that make negligible contributions to the overall isolation provided by the disposal system.

Scope of Performance Assessments. Section 191.13 requires the implementing agencies to evaluate compliance through performance assessments as defined in § 191.12(q). The Agency assumes that such performance assessments need not consider categories of events or processes that are estimated to have less than one chance in 10,000 of occurring over 10,000 years. Furthermore, the performance assessments need not evaluate in detail the releases from all events and processes estimated to have a greater likelihood of occurrence. Some of these events and processes may be omitted from the performance assessments if there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by such omissions.

Compliance with § 191.13. The Agency assumes that, whenever practicable, the implementing agency will assemble all of the results of the performance assessments to determine compliance with § 191.13 into a "complementary cumulative distribution function" that indicates the probability of exceeding various levels of cumulative release. When the uncertainties in parameters are considered in a performance assessment, the effects of the uncertainties considered can be incorporated into a single such distribution function for each disposal system considered. The Agency assumes that a disposal system can be considered to be in compliance with § 191.13 if this single distribution function meets the requirements of § 191.13(a).

Compliance with §§ 191.15 and 191.16. When the uncertainties in undisturbed performance of a disposal system are considered, the implementing agencies need not require that a very large percentage of the range of estimated radiation exposures or radionuclide concentrations fall below limits established in §§ 191.15 and 191.16, respectively. The Agency assumes that compliance can be determined based upon "best estimate" predictions (e.g., the mean or the median of the appropriate distribution, whichever is higher).

Institutional Controls. To comply with § 191.14(a), the implementing agency will assume that none of the active institutional controls prevent or reduce radionuclide releases for more than 100 years after disposal. However, the Federal Government is committed to retaining ownership of all disposal sites for spent nuclear fuel and high-level and transuranic radioactive wastes and will establish appropriate markers and records, consistent with § 191.14(c). The Agency assumes that, as long as such passive institutional controls endure and are understood, they: (1) Can be effective in deterring systematic or persistent exploitation of these disposal sites; and (2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency. However, the Agency believes that passive institutional controls can never be assumed to eliminate the chance of inadvertent and intermittent human intrusion into these disposal sites.

Consideration of Inadvertent Human Intrusion into Geologic Repositories. The most speculative potential disruptions of a mined geologic repository are those associated with inadvertent human intrusion. Some types of intrusion would have virtually no effect on a repository's containment of waste. On the other hand, it is possible to conceive of intrusions (involving widespread

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societal loss of knowledge regarding radioactive wastes) that could result in major disruptions that no reasonable repository selection or design precautions could alleviate. The Agency believes that the most productive consideration of inadvertent intrusion concerns those realistic possibilities that may be usefully mitigated by repository design, site selection, or use of passive controls (although passive institutional controls should not be assumed to completely rule out the possibility of intrusion). Therefore, inadvertent and intermittent intrusion by exploratory drilling for resources (other than any provided by the disposal system itself) can be the most severe intrusion scenario assumed by the implementing agencies. Furthermore, the implementing agencies can assume that passive institutional controls or the intruders' own exploratory procedures are adequate for the intruders to soon detect, or be warned of, the incompatibility of the area with their activities.

Frequency and Severity of Inadvertent Human Intrusion into Geologic Repositories. The implementing agencies should consider the effects of each particular disposal system's site, design, and passive institutional controls in judging the likelihood and consequences of such inadvertent exploratory drilling. However, the Agency assumes that the likelihood of such inadvertent and intermittent drilling need not be taken to be greater than 30 boreholes per square kilometer of repository area per 10,000 years for geologic repositories in proximity to sedimentary rock formations, or more than 3 boreholes per square kilometer per 10,000 years for repositories in other geologic formations. Furthermore, the Agency assumes that the consequences of such inadvertent drilling need not be assumed to be more severe than: (1) Direct release to the land surface of all the ground water in the repository horizon that would promptly flow through the newly created borehole to the surface due to natural lithostatic pressure—or (if pumping would be required to raise water to the surface) release of 200 cubic meters of ground water pumped to the surface if that much water is readily available to be pumped; and (2) creation of a ground water flow path with a permeability typical of a borehole filled by the soil or gravel that would normally settle into an open hole over time—not the permeability of a carefully sealed borehole.

Appendix B

(b) Any license may be revoked, suspended, or modified, in whole or in part:

(1) For any material false statement in the application or in any statement of fact required under section 182 of the Act,

(2) Because of conditions revealed by the application or statement of fact or any report, record, inspection or other means that would warrant the Commission to refuse to grant a license on an original application,

(3) For willful violation of, or failure to observe any of the terms and conditions of the Act, or the license, or of any rule, regulation, or order of the Commission, or

(4) For any conduct determined by the Commission to be a hazard to safe operation of the facility.

Subpart H—Enforcement

§ 55.71 Violations.

(a) An injunction or other court order may be obtained prohibiting any violation of any provision of:

(1) The Atomic Energy Act of 1954, as amended;

(2) Title II of the Energy Reorganization Act of 1974, as amended; or

(3) Any regulation or order issued under these Acts.

(b) A court order may be obtained for the payment of a civil penalty imposed under section 234 of the Aomic Energy Act for violation of:

(1) Sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Atomic Energy Act;

(2) Section 206 of the Energy Reorganization Act of 1974;

(3) Any rule, regulation, or order issued under these Acts;

(4) Any term, condition, or limitation of any license issued under these Acts; or

(5) For any violation for which a license may be revoked under section 186 of the Atomic Energy Act.

(c) Any person who willfully violates any provision of the Atomic Energy Act or any regulation issued under the Act, including the regulations in this part, may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment, or both, as provided by law.

PART 60—DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

Subpart A—General Provisions

Sec.

Subpart B—Licenses

PREAPPLICATION REVIEW

LICENSE APPLICATIONS

CONSTRUCTION AUTHORIZATION

LICENSE ISSUANCE AND AMENDMENT

PERMANENT CLOSURE

AUTHORITY: Secs. 51, 53, 62, 63, 65, 81, 161, 182, 183, 68 Stat. 929, 930, 932, 933, 935, 948, 953, 954, as amended (42 U.S.C. 2071, 2073, 2092, 2093, 2095, 2111, 2201, 2232, 2233); secs. 202, 206, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846); secs. 10 and 14, Pub. L. 95-601, 92 Stat. 2951 (42 U.S.C. 2021a and 5851); sec. 102, Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332); secs. 114, 121, Pub. L. 97-425, 96 Stat. 2213, 2228, as amended (42 U.S.C. 10134, 10141).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), §§ 60.10, 60.71 to 60.75 are issued under sec. 161o, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

SOURCE: 46 FR 13980, Feb. 25, 1981, unless otherwise noted.

Subpart A—General Provisions

§ 60.1 Purpose and scope.

This part prescribes rules governing the licensing of the U.S. Department of Energy to receive and possess source, special nuclear, and byproduct material at a geologic repository operations area sited, constructed, or operated in accordance with the Nuclear Waste Policy Act of 1982. This part does not apply to any activity licensed under another part of this chapter.

[51 FR 27162, July 30, 1986]

§ 60.2 Definitions.

As used in this part:

"Accessible environment" means: (1) The atmosphere, (2) the land surface, (3) surface water, (4) oceans, and (5) the portion of the lithosphere that is outside the controlled area.

"Affected Indian Tribe" means any Indian Tribe (1) within whose reservation boundaries a repository for high-level radioactive waste or spent fuel is proposed to be located; or (2) whose Federally defined possessory or usage rights to other lands outside of the reservation's boundaries arising out of Congressionally ratified treaties or other Federal law may be substantially and adversely affected by the locating of such a facility; *Provided*, That the Secretary of the Interior finds, upon the petition of the appropriate governmental officials of the Tribe, that such effects are both substantial and adverse to the Tribe.

"Anticipated processes and events" means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved. To the extent reasonable in the light of the geologic record, it shall be assumed that those processes operating in the geologic setting during the Quaternary Period continue to operate but with the perturbations caused by the presence of emplaced radioactive waste superimposed thereon.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Candidate area" means a geologic and hydrologic system within which a geologic repository may be located.

"Commencement of construction" means clearing of land, surface or subsurface excavation, or other substantial action that would adversely affect the environment of a site, but does not include changes desirable for the temporary use of the land for public recreational uses, site characterization activities, other preconstruction monitoring and investigation necessary to establish background information related to the suitability of a site or to the protection of environmental values, or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Controlled area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the accessible environment.

"Disturbed zone" means that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered barrier system" means the waste packages and the underground facility.

"Geologic repository" means a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes: (1) The geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste.

"Geologic repository operations area" means a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

"Groundwater" means all water which occurs below the land surface.

"High-level radioactive waste" or "HLW" means: (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

"HLW facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat 1244).[1]

"Host rock" means the geologic medium in which the waste is emplaced.

"Important to safety," with reference to structures, systems, and components means those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure.

"Isolation" means inhibiting the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

"Permanent closure" means final backfilling of the underground facility and the sealing of shafts and boreholes.

"Performance confirmation" means the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met.

"Public Document Room" means the place at 2120 L Street NW., Washington, D.C., at which records of the Commission will ordinarily be made available for public inspection and any other place, the location of which has been published in the FEDERAL REGISTER, at which public records of the Commission pertaining to a particular geologic repository are made available for public inspection.

"Radioactive waste" or "waste" means HLW and other radioactive materials other than HLW that are received for emplacement in a geologic repository.

"Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

"Retrieval" means the act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal.

"Saturated zone" means that part of the earth's crust beneath the regional water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

"Site" means the location of the controlled area.

"Site characterization" means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic repository, but does not include preliminary borings and geophysical testing needed to decide whether site

[1] These are DOE "facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such Act [the Atomic Energy Act]" and "Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive wastes generated by [DOE], which are not used for, or are part of, research and development activities."

characterization should be undertaken.

"Unanticipated processes and events" means those processes and events affecting the geologic setting that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which are nevertheless sufficiently credible to warrant consideration. Unanticipated processes and events may be either natural processes or events or processes and events initiated by human activities other than those activities licensed under this part. Processes and events initiated by human activities may only be found to be sufficiently credible to warrant consideration if it is assumed that: (1) The monuments provided for by this part are sufficiently permanent to serve their intended purpose; (2) the value to future generations of potential resources within the site can be assessed adequately under the applicable provisions of this part; (3) an understanding of the nature of radioactivity, and an appreciation of its hazards, have been retained in some functioning institutions; (4) institutions are able to assess risk and to take remedial action at a level of social organization and technological competence equivalent to, or superior to, that which was applied in initiating the processes or events concerned; and (5) relevant records are preserved, and remain accessible, for several hundred years after permanent closure.

"Underground facility" means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

"Unrestricted area" means any area, access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

"Unsaturated zone" means the zone between the land surface and the regional water table. Generally, fluid pressure in this zone is less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies the fluid pressure locally may be greater than atmospheric.

"Waste form"means the radioactive waste materials and any encapsulating or stabilizing matrix.

"Waste package" means the waste form and any containers, shielding, packing and other absorbent materials immediately surrounding an individual waste container.

"Water table" means that surface in a groundwater body at which the water pressure is atmospheric.

[48 FR 28217, June 21, 1983, as amended at 50 FR 29647, July 22, 1985; 51 FR 27162, July 30, 1986; 53 FR 43421, Oct. 27, 1988]

§ 60.3 License required.

(a) DOE shall not receive or possess source, special nuclear, or byproduct material at a geologic repository operations area except as authorized by a license issued by the Commission pursuant to this part.

(b) DOE shall not commence construction of a geologic repository operations area unless it has filed an application with the Commission and has obtained construction authorization as provided in this part. Failure to comply with this requirement shall be grounds for denial of a license.

§ 60.4 Communications and records.

(a) Except where otherwise specified, all communications and reports concerning the regulations in this part and applications filed under them should be addressed to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Communications reports, and applications may be delivered in person at the Commission's offices at 2120 L Street NW., Washington DC, or 11555 Rockville Pike, Rockville, Maryland.

(b) Each record required by this part must be legible throughout the retention period specified by each Commission regulation. The record may be the original or a reproduced copy or a microform provided that the copy or microform is authenticated by authorized personnel and that the microform is capable of producing a clear copy throughout the required retention period. The record may also be stored

in electronic media with the capability for producing legible, accurate, and complete records during the required retention period. Records such as letters, drawings, specifications, must include all pertinent information such as stamps, initials, and signatures. The licensee shall maintain adequate safeguards against tampering with and loss of records.

[53 FR 19251, May 27, 1988, as amended at 53 FR 43421, Oct. 27, 1988]

§ 60.5 Interpretations.

Except as specifically authorized by the Commission, in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be considered binding upon the Commission.

§ 60.6 Exemptions.

The Commission may, upon application by DOE, any interested person, or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law, will not endanger life or property or the common defense and security, and are otherwise in the public interest.

§ 60.7 License not required for certain preliminary activities.

The requirement for a license set forth in § 60.3(a) of this part is not applicable to the extent that DOE receives and possesses source, special nuclear, and byproduct material at a geologic repository:

(a) For purposes of site characterization; or

(b) For use, during site characterization or construction, as components of radiographic, radiation monitoring, or similar equipment or instrumentation.

§ 60.8 Reporting, recordkeeping, and application requirements: OMB approval not required.

The information collection requirements contained in this part affect fewer than ten persons. Therefore, under section 3506(c)(5) of the Paperwork Reduction Act of 1980 (Pub. L. 96-511), OMB clearance is not required for these information collection requirements.

[47 FR 13774, Apr. 1, 1982]

§ 60.9 Employee protection.

(a) Discrimination by a Commission licensee, an applicant for a Commission license, or a contractor or subcontractor of a Commission licensee or applicant against an employee for engaging in certain protected activities is prohibited. Discrimination includes discharge and other actions that relate to compensation, terms, conditions, and privileges of employment. The protected activities are established in section 210 of the Energy Reorganization Act of 1974, as amended, and in general are related to the administration or enforcement of a requirement imposed under the Atomic Energy Act or the Energy Reorganization Act.

(1) The protected activities include but are not limited to:

(i) Providing the Commission information about possible violations of requirements imposed under either of the above statutes;

(ii) Requesting the Commission to institute action against his or her employer for the administration or enforcement of these requirements; or

(iii) Testifying in any Commission proceeding.

(2) These activities are protected even if no formal proceeding is actually initiated as a result of the employee assistance or participation.

(3) This section has no applicaton to any employee alleging discrimination prohibited by this section who, acting without direction from his or her employer (or the employer's agent), deliberately causes a violation of any requirement of the Energy Reorganization Act of 1974, as amended, or the Atomic Energy Act of 1954, as amended.

(b) Any employee who believes that he or she has been discharged or otherwise discriminated against by any person for engaging in the protected activities specified in paragraph (a)(1) of this section may seek a remedy for the discharge or discrimination through an administrative proceeding in the Department of Labor. The administrative proceeding must be initi-

ated within 30 days after an alleged violation occurs by filing a complaint alleging the violation with the Department of Labor, Employment Standards Administration, Wage and Hour Division. The Department of Labor may order reinstatement, back pay, and compensatory damages.

(c) A violation of paragraph (a) of this section by a Commission licensee, an applicant for a Commission license, or a contractor or subcontractor of a Commission licensee or applicant may be grounds for:

(1) Denial, revocation, or suspension of the license.

(2) Imposition of a civil penalty on the licensee or applicant.

(3) Other enforcement action.

(d) Actions taken by an employer, or others, which adversely affect an employee may be predicated upon nondiscriminatory grounds. The prohibition applies when the adverse action occurs because the employee has engaged in protected activities. An employee's engagement in protected activities does not automatically render him or her immune from discharge or discipline for legitimate reasons or from adverse action dictated by nonprohibited considerations.

(e) Each licensee and each applicant shall post Form NRC-3, "Notice to Employees," on its premises. Posting must be at locations sufficient to permit employees protected by this section to observe a copy on the way to or from their place of work. Premises must be posted not later than 30 days after an application is docketed and remain posted while the application is pending before the Commission, during the term of the license, and for 30 days following license termination.

NOTE: Copies of Form NRC-3 may be obtained by writing to the Regional Administrator of the appropriate U.S. Nuclear Regulatory Commission Regional Office listed in Appendix D, Part 20 of this chapter.

[47 FR 30456, July 14, 1982, as amended at 52 FR 31612, Aug. 21, 1987]

§ 60.10 Completeness and accuracy of information.

(a) Information provided to the Commission by an applicant for a license or by a licensee or information required by statute or by the Commission's regulations, orders, or license conditions to be maintained by the applicant or the licensee shall be complete and accurate in all material respects.

(b) Each applicant or licensee shall notify the Commission of information identified by the applicant or licensee as having for the regulated activity a significant implication for public health and safety or common defense and security. An applicant or licensee violates this paragraph only if the applicant or licensee fails to notify the Commission of information that the applicant or licensee has identified as having a significant implication for public health and safety or common defense and security. Notification shall be provided to the Administrator of the appropriate Regional Office within two working days of identifying the information. This requirement is not applicable to information which is already required to be provided to the Commission by other reporting or updating requirements.

[52 FR 49372, Dec. 31, 1987]

Subpart B—Licenses

PREAPPLICATION REVIEW

§ 60.15 Site characterization.

(a) Prior to submittal of an application for a license to be issued under this part DOE shall conduct a program of site characterization with respect to the site to be described in such application.

(b) Unless the Commission determines with respect to the site described in the application that it is not necessary, site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced.

(c) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted in such a manner as to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

(2) The number of exploratory boreholes and shafts shall be limited to the extent practical consistent with obtaining the information needed for site characterization.

(3) To the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for underground facility construction and operation or where large unexcavated pillars are planned.

(4) Subsurface exploratory drilling, excavation, and in situ testing before and during construction shall be planned and coordinated with geologic repository operations area design and construction.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28219, June 21, 1983. Redesignated and amended at 51 FR 27162, July 30, 1986; 54 FR 27871, July 3, 1989]

§ 60.16 Site characterization plan required.

Before proceeding to sink shafts at any area which has been approved by the President for site characterization, DOE shall submit to the Director, for review and comment, a site characterization plan for such area. DOE shall defer the sinking of such shafts until such time as there has been an opportunity for Commission comments thereon to have been solicited and considered by DOE.

[51 FR 27162, July 30, 1986]

§ 60.17 Contents of site characterization plan.

The site characterization plan shall contain—

(a) A general plan for site characterization activities to be conducted at the area to be characterized, which general plan shall include:

(1) A description of such area, including information on quality assurance programs that have been applied to the collection, recording, and retention of information used in preparing such description.

(2) A description of such site characterization activities, including the following—

(i) The extent of planned excavations;

(ii) Plans for any onsite testing with radioactive material, including radioactive tracers, or nonradioactive material;

(iii) Plans for any investigation activities that may affect the capability of such area to isolate high-level radioactive waste;

(iv) Plans to control any adverse impacts from such site characterization activities that are important to safety or that are important to waste isolation; and

(v) Plans to apply quality assurance to data collection, recording, and retention.

(3) Plans for the decontamination and decommissioning of such area, and for the mitigation of any significant adverse environmental impacts caused by site characterization activities, if such area is determined unsuitable for application for a construction authorization for a geologic repository operations area;

(4) Criteria, developed pursuant to section 112(a) of the Nuclear Waste Policy Act of 1982, to be used to determine the suitability of such area for the location of a geologic repository; and

(5) Any other information which the Commission, by rule or order, requires.

(b) A description of the possible waste form or waste package for the high-level radioactive waste to be emplaced in such geologic repository, a description (to the extent practicable) of the relationship between such waste form or waste package and the host rock at such area, and a description of the activities being conducted by DOE with respect to such possible waste form or waste package or their relationship; and

(c) A conceptual design for the geologic repository operations area that takes into account likely site-specific requirements.

[51 FR 27163, July 30, 1986]

§ 60.18 Review of site characterization activities.[2]

(a) The Director shall cause to be published in the FEDERAL REGISTER a notice that a site characterization plan has been received from DOE and that a staff review of such plan has begun. The notice shall identify the area to be characterized and the NRC staff members to be consulted for further information.

(b) The Director shall make a copy of the site characterization plan available at the Public Document Room. The Director shall also transmit copies of the published notice of receipt to the Governor and legislature of the State in which the area to be characterized is located and to the governing body of any affected Indian Tribe. The Director shall provide an opportunity, with respect to any area to be characterized, for the State in which such area is located and for affected Indian Tribes to present their views on the site characterization plan and their suggestions with respect to comments thereon which may be made by NRC. In addition, the Director shall make NRC staff available to consult with States and affected Indian Tribes as provided in Subpart C of this part.

(c) The Director shall review the site characterization plan and prepare a site characterization analysis with respect to such plan. In the preparation of such site characterization analysis, the Director may invite and consider the views of interested persons on DOE's site characterization plan and may review and consider comments made in connection with public hearings held by DOE.

(d) The Director shall provide to DOE the site characterization analysis together with such additional comments as may be warranted. These comments shall include either a statement that the Director has no objection to the DOE's site characterization program, if such a statement is appropriate, or specific objections with respect to DOE's program for characterization of the area concerned. In addition, the Director may make specific recommendations pertinent to DOE's site characterization program.

(e) If DOE's planned site characterization activities include onsite testing with radioactive material, including radioactive tracers, the Director's comments shall include a determination regarding whether or not the Commission concurs that the proposed use of such radioactive material is necessary to provide data for the preparation of the environmental reports required by law and for an application to be submitted under § 60.22 of this part.

(f) The Director shall publish in the FEDERAL REGISTER a notice of availability of the site characterization anaylsis and a request for public comment. A reasonable period, not less than 90 days, shall be allowed for comment. Copies of the site characterization analysis and of the comments received shall be made available at the Public Document Room.

(g) During the conduct of site characterization activities, DOE shall report not less than once every six months to the Commission on the nature and extent of such activities and the information that has been developed, and on the progress of waste form and waste package research and development. The semiannual reports shall include the results of site characterization studies, the identification of new issues, plans for additional studies to resolve new issues, elimination of planned studies no longer necessary, identification of decision points reached and modifications to schedules where appropriate. DOE shall also report its progress in developing the design of a geologic repository operations area appropriate for the area being characterized, noting when key design parameters or features which depend upon the results of site characterization will be established. Other topics related to site characterization

[2] In addition to the review of site characterization activities specified in this section, the Commission contemplates an ongoing review of other information on site investigation and site characterization, in order to allow early identification of potential licensing issues for timely resolution. This activity will include, for example, a review of the environmental assessments prepared by DOE at the time of site nomination, and review of issues related to long lead time exploratory shaft planning and procurement actions by DOE prior to issuance of site characterization plans.

shall also be covered if requested by the Director.

(h) During the conduct of site characterization activities, NRC staff shall be permitted to visit and inspect the locations at which such activities are carried out and to observe excavations, borings, and in situ tests as they are done.

(i) The Director may comment at any time in writing to DOE, expressing current views on any aspect of site characterization. In particular, such comments shall be made whenever the Director, upon review of comments invited on the site characterization analysis or upon review of DOE's semiannual reports, determines that there are substantial new grounds for making recommendations or stating objections to DOE's site characterization program. The Director shall invite public comment on any comments which the Director makes to DOE upon review of the DOE semiannual reports or on any other comments which the Director makes to DOE on site characterization.

(j) The Director shall transmit copies of the site characterization analysis and all comments to DOE made by the Director under this section to the Governor and legislature of the State in which the area to be characterized is located and to the governing body of any affected Indian Tribe. When transmitting the site characterization analysis under this paragraph, the Director shall invite the addressees to review and comment thereon.

(k) All correspondence between DOE and the NRC under this section, including the reports described in paragraph (g), shall be placed in the Public Document Room.

(l) The activities described in paragraphs (a) through (k) of this section constitute informal conference between a prospective applicant and the staff, as described in § 2.101(a)(1) of this chapter, and are not part of a proceeding under the Atomic Energy Act of 1954, as amended. Accordingly, neither the issuance of a site characterization analysis nor any other comments of the Director made under this section constitutes a commitment to issue any authorization or license or in any way affect the authority of the Commission, the Atomic Safety and Licensing Appeal Board, Atomic Safety and Licensing Boards, other presiding officers, or the Director, in any such proceeding.

[51 FR 27163, July 30, 1986]

LICENSE APPLICATIONS

§ 60.21 Content of application.

(a) An application shall consist of general information and a Safety Analysis Report. An environmental impact statement shall be prepared in accordance with the Nuclear Waste Policy Act of 1982, as amended, and shall accompany the application. Any Restricted Data or National Security Information shall be separated from unclassified information.

(b) The general information shall include:

(1) A general description of the proposed geologic repository identifying the location of the geologic repository operations area, the general character of the proposed activities, and the basis for the exercise of licensing authority by the Commission.

(2) Proposed schedules for construction, receipt of waste, and emplacement of wastes at the proposed geologic repository operations area.

(3) A certification that DOE will provide at the geologic repository operations area such safeguards as it requires at comparable surface facilities (of DOE) to promote the common defense and security.

(4) A description of the physical security plan for protection against radiological sabotage. Since the radiation hazards associated with high-level wastes make them inherently unattractive as a target for theft or diversion, no detailed information need be submitted on protection against theft or diversion.

(5) A description of site characterization work actually conducted by DOE at all sites considered in the application and, as appropriate, explanations of why such work differed from the description of the site characterization program described in the Site Characterization Report for each site.

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they affect isolation within the controlled area.

(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(E) An analysis of the performance of the major design structures, systems, and components, both surface and subsurface, to identify those that are important to safety. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, in situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. This analysis shall consider—(i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

(4) A description of the quality assurance program to be applied to the structures, systems, and components important to safety and to the engineered and natural barriers important to waste isolation.

(5) A description of the kind, amount, and specifications of the radioactive material proposed to be received and possessed at the geologic repository operations area.

(6) An identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of license specifications. Special attention shall be given to those items that may significantly influence the final design.

(7) A description of the program for control and monitoring of radioactive effluents and occupational radiation exposures to maintain such effluents and exposures in accordance with the requirements of Part 20 of this chapter.

(8) A description of the controls that the applicant will apply to restrict access and to regulate land use at the site and adjacent areas, including a conceptual design of monuments which would be used to identify the controlled area after permanent closure.

(9) Plans for coping with radiological emergencies at any time prior to permanent closure and decontamination or dismantlement of surface facilities.

(10) A description of the nuclear material control and accounting program.

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

(12) A description of plans for retrieval and alternate storage of the radioactive wastes should the geologic repository prove to be unsuitable for disposal of radioactive wastes.

(13) An identification and evaluation of the natural resources of the geologic setting, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the geologic repository to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscoverd deposits, shall be conducted for the site and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The estimate of net value shall take into account current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

(14) An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, which require research and development to confirm the adequacy of design. For structures, sys-

tems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

(15) The following information concerning activities at the geologic repository operations area:

(i) The organizational structure of DOE as it pertains to construction and operation of the geologic repository operations area including a description of any delegations of authority and assignments of responsibilities, whether in the form of regulations, administrative directives, contract provisions, or otherwise.

(ii) Identification of key positions which are assigned responsibility for safety at and operation of the geologic repository operations area.

(iii) Personnel qualifications and training requirements.

(iv) Plans for startup activities and startup testing.

(v) Plans for conduct of normal activities, including maintenance, surveillance, and periodic testing of structures, systems, and components of the geologic repository operation area.

(vi) Plans for permanent closure and plans for the decontamination or dismantlement of surface facilities.

(vii) Plans for any uses of the geologic repository operations area for purposes other than disposal of radioactive wastes, with an analysis of the effects, if any, that such uses may have upon the operation of the structures, systems, and components important to safety and the engineered and natural barriers important to waste isolation.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28219, June 21, 1983; 54 FR 27871, July 3, 1989]

§ 60.22 Filing and distribution of application.

(a) An application for a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area at a site which has been characterized, and any amendments thereto, and an accompanying environmental impact statement and any supplements, shall be signed by the Secretary of Energy or the Secretary's authorized representative and shall be filed in triplicate with the Director.

(b) Each portion of such application and any amendments, and each environmental impact statement and any supplements, shall be accompanied by 30 additional copies. Another 120 copies shall be retained by DOE for distribution in accordance with written instructions from the Director or the Director's designee.

(c) DOE shall, upon notification of the appointment of an Atomic Safety and Licensing Board, update the application, eliminating all superseded information, and supplement the environmental impact statement if necessary, and serve the updated application and environmental impact statement (as it may have been supplemented) as directed by the Board. At that time DOE shall also serve one such copy of the application and environmental impact statement on the Atomic Safety and Licensing Appeal Panel. Any subsequent amendments to the application or supplements to the environmental impact statement shall be served in the same manner.

(d) At the time of filing of an application and any amendments thereto, one copy shall be made available in an appropriate location near the proposed geologic repository operations area (which shall be a public document room, if one has been established) for inspection by the public and updated as amendments to the application are made. The environmental impact statement and any supplements thereto shall be made available in the same manner. An updated copy of the application, and the environmental impact statement and supplements, shall be produced at any public hearing held by the Commission on the application, for use by any party to the proceeding.

(e) The DOE shall certify that the updated copies of the application, and the environmental impact statement as it may have been supplemented, as referred to in paragraphs (c) and (d) of this section, contain the current contents of such documents submitted

in accordance with the requirements of this part.

[54 FR 27871, July 3, 1989]

§ 60.23 Elimination of repetition.

In its application, environmental report, or Site Characterization Report, the DOE may incorporate by reference information contained in previous applications, statements, or reports filed with the Commission: *Provided,* That such references are clear and specific and that copies of the information so incorporated are available in the public document room located near the site of the proposed geologic repository.

§ 60.24 Updating of application and environmental impact statement.

(a) The application shall be as complete as possible in the light of information that is reasonably available at the time of docketing.

(b) The DOE shall update its application in a timely manner so as to permit the Commission to review, prior to issuance of a license:

(1) Additional geologic, geophysical, geochemical, hydrologic, meteorologic and other data obtained during construction.

(2) Conformance of construction of structures, systems, and components with the design.

(3) Results of research programs carried out to confirm the adequacy of designs.

(4) Other information bearing on the Commission's issuance of a license that was not available at the time a construction authorization was issued.

(c) The DOE shall supplement its environmental impact statement in a timely manner so as to take into account the environmental impacts of any substantial changes in its proposed actions or any significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

[46 FR 13980, Feb. 25, 1981, as amended at 54 FR 27872, July 3, 1989]

CONSTRUCTION AUTHORIZATION

§ 60.31 Construction authorization.

Upon review and consideration of an application and environmental impact statement submitted under this part, the Commission may authorize construction if it determines:

(a) *Safety.* That there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository operations area of the design proposed without unreasonable risk to the health and safety of the public. In arriving at this determination, the Commission shall consider whether:

(1) DOE has described the proposed geologic repository including but not limited to: (i) The geologic, geophysical, geochemical and hydrologic characteristics of the site; (ii) the kinds and quantities of radioactive waste to be received, possessed, stored, and disposed of in the geologic repository operations area; (iii) the principal architectural and engineering criteria for the design of the geologic repository operations area; (iv) construction procedures which may affect the capability of the geologic repository to serve its intended function; and (v) features or components incorporated in the design for the protection of the health and safety of the public.

(2) The site and design comply with the performance objectives and criteria contained in Subpart E of this part.

(3) The DOE's quality assurance program complies with the requirements of Subpart G of this part.

(4) The DOE's personnel training program complies with the criteria contained in Subpart H of this part.

(5) The DOE's emergency plan complies with the criteria contained in Subpart I of this part.

(6) The DOE's proposed operating procedures to protect health and to minimize danger to life or property are adequate.

(b) *Common defense and security.* That there is reasonable assurance that the activities proposed in the application will not be inimical to the

common defense and security. A DOE certification that it will provide at the geologic repository operations area such safeguards as it requires at comparable DOE surface facilities to promote the common defense and security will constitute a rebuttable presumption of noninimicality to the common defense and security.

(c) *Environmental.* That, after weighing the environmental, economic, technical and other benefits against environmental costs and considering available alternatives, the action called for is issuance of the construction authorization, with any appropriate conditions to protect environmental values.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28220, June 21, 1983; 54 FR 27872, July 3, 1989]

§ 60.32 Conditions of construction authorization.

(a) A construction authorization shall include such conditions as the Commission finds to be necessary to protect the health and safety of the public, the common defense and security, or environmental values.

(b) The Commission will incorporate in the construction authorization provisions requiring DOE to furnish periodic or special reports regarding: (1) Progress of construction, (2) any data about the site obtained during construction which are not within the predicted limits upon which the facility design was based, (3) any deficiencies in design and construction which, if uncorrected, could adversely affect safety at any future time, and (4) results of research and development programs being conducted to resolve safety questions.

(c) The construction authorization will include restrictions on subsequent changes to the features of the geologic repository and the procedures authorized. The restrictions that may be imposed under this paragraph can include measures to prevent adverse effects on the geologic setting as well as measures related to the design and construction of the geologic repository operations area. These restrictions will fall into three categories of descending importance to public health and safety as follows: (1) Those features and procedures which may not be changed without: (i) 60 days prior notice to the Commission (ii) 30 days notice of opportunity for a prior hearing, and (iii) prior Commission approval; (2) those features and procedures which may not be changed without (i) 60 days prior notice to the Commission, and (ii) prior Commission approval; and (3) those features and procedures which may not be changed without 60 days notice to the Commission. Features and procedures falling in paragraph (c)(3) of this section may not be changed without prior Commission approval if the Commission, after having received the required notice, so orders.

(d) A construction authorization shall be subject to the limitation that a license to receive and possess source, special nuclear, or byproduct material at the geologic repository operations area shall not be issued by the Commission until (1) the DOE has updated its application as specified in § 60.24, and (2) the Commission has made the findings stated in § 60.41.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28221, June 21, 1983]

§ 60.33 Amendment of construction authorization.

(a) An application for amendment of a construction authorization shall be filed with the Commission fully describing any changes desired and following as far as applicable the format prescribed in § 60.21.

(b) In determining whether an amendment of a construction authorization will be approved, the Commission will be guided by the considerations which govern the issuance of the initial construction authorization, to the extent applicable.

License Issuance and Amendment

§ 60.41 Standards for issuance of a license.

A license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area may be issued by the Commission upon finding that:

(a) Construction of the geologic repository operations area has been substantially completed in conformity

with the application as amended, the provisions of the Atomic Energy Act, and the rules and regulations of the Commission. Construction may be deemed to be substantially complete for the purposes of this paragraph if the construction of (1) surface and interconnecting structures, systems, and components, and (2) any underground storage space required for initial operation are substantially complete.

(b) The activities to be conducted at the geologic repository operations area will be in conformity with the application as amended, the provisions of the Atomic Energy Act and the Energy Reorganization Act, and the rules and regulations of the Commission.

(c) The issuance of the license will not be inimical to the common defense and security and will not constitute an unreasonable risk to the health and safety of the public. A DOE certification that it will provide at the geologic repository operations area such safeguards as it requires at comparable DOE facilities to promote the common defense and security, will constitute a rebuttable presumption of non-inimicality to the common defense and security.

(d) All applicable requirements of Part 51 have been satisfied.

§ 60.42 Conditions of license.

(a) A license issued pursuant to this part shall include such conditions, including license specifications, as the Commission finds to be necessary to protect the health and safety of the public, the common defense and security, and environmental values.

(b) Whether stated therein or not, the following shall be deemed conditions in every license issued:

(1) The license shall be subject to revocation, suspension, modification, or amendment for cause as provided by the Atomic Energy Act and the Commission's regulations.

(2) The DOE shall at any time while the license is in effect, upon written request of the Commission, submit written statements to enable the Commission to determine whether or not the license should be modified, suspended or revoked.

(3) The license shall be subject to the provisions of the Atomic Energy Act now or hereafter in effect and to all rules, regulations, and orders of the Commission. The terms and conditions of the license shall be subject to amendment, revision, or modification, by reason of amendments to or by reason of rules, regulations, and orders issued in accordance with the terms of the Atomic Energy Act.

(c) Each license shall be deemed to contain the provisions set forth in Section 183 b-d, inclusive, of the Atomic Energy Act, whether or not these provisions are expressly set forth in the license.

§ 60.43 License specification.

(a) A license issued under this part shall include license conditions derived from the analyses and evaluations included in the application, including amendments made before a license is issued, together with such additional conditions as the Commission finds appropriate.

(b) License conditions shall include items in the following categories:

(1) Restrictions as to the physical and chemical form and radioisotopic content of radioactive waste.

(2) Restrictions as to size, shape, and materials and methods of construction of radioactive waste packaging.

(3) Restrictions as to the amount of waste permitted per unit volume of storage space considering the physical characteristics of both the waste and the host rock.

(4) Requirements relating to test, calibration, or inspection to assure that the foregoing restrictions are observed.

(5) Controls to be applied to restricted access and to avoid disturbance to the controlled area and to areas outside the controlled area where conditions may affect isolation within the controlled area.

(6) Administrative controls, which are the provisions relating to organization and management, procedures, recordkeeping, review and audit, and reporting necessary to assure that activities at the facility are conducted in a safe manner and in conformity with the other license specifications.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28221, June 21, 1983]

§ 60.44 Changes, tests, and experiments.

(a)(1) Following authorization to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area, the DOE may (i) make changes in the geologic repository operations area as described in the application, (ii) make changes in the procedures as described in the application, and (iii) conduct tests or experiments not described in the application, without prior Commission approval, provided the change, test, or experiment involves neither a change in the license conditions incorporated in the license nor an unreviewed safety question.

(2) A proposed change, test, or experiment shall be deemed to involve an unreviewed safety question if (i) the likelihood of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the application is increased, (ii) the possibility of an accident or malfunction of a different type than any previously evaluated in the application is created, or (iii) the margin of safety as defined in the basis for any license condition is reduced.

(b) The DOE shall maintain records of changes in the geologic repository operations area and of changes in procedures made pursuant to this section, to the extent that such changes constitute changes in the geologic repository operations area or procedures as described in the application. Records of tests and experiments carried out pursuant to paragraph (a) of this section shall also be maintained. These records shall include a written safety evaluation which provides the basis for the determination that the change, test, or experiment does not involve an unreviewed safety question. The DOE shall prepare annually, or at such shorter intervals as may be specified in the license, a report containing a brief description of such changes, tests, and experiments, including a summary of the safety evaluation of each. The DOE shall furnish the report to the appropriate NRC Regional Office shown in Appendix D of Part 20 of this chapter with a copy t the Director, Office of Nuclear Materi al Safety and Safeguards, U.S. Nuclea Regulatory Commission, Washingto D.C. 20555. Any report submitted pur suant to this paragraph shall be mad a part of the public record of the li censing proceedings.

[46 FR 13980, Feb. 25, 1981, as amended a 52 FR 31612, Aug. 21, 1987]

§ 60.45 Amendment of license.

(a) An application for amendment o a license may be filed with the Com mission fully describing the change desired and following as far as applica ble the format prescribed for license applications.

(b) In determining whether an amendment of a license will be approved, the Commission will be guided by the considerations that govern the issuance of the initial license, to the extent applicable.

§ 60.46 Particular activities requiring license amendment.

(a) Unless expressly authorized in the license, an amendment of the license shall be required with respect to any of the following activities:

(1) Any action which would make emplaced high-level radioactive waste irretrievable or which would substantially increase the difficulty of retrieving such emplaced waste.

(2) Dismantling of structures.

(3) Removal or reduction of controls applied to restrict access to or avoid disturbance of the controlled area and to areas outside the controlled area where conditions may affect isolation within the controlled area.

(4) Destruction or disposal of records required to be maintained under the provisions of this part.

(5) Any substantial change to the design or operating procedures from that specified in the license.

(6) Permanent closure.

(7) Any other activity involving an unreviewed safety question.

(b) An application for such an amendment shall be filed, and shall be reviewed, in accordance with the provisions of § 60.45.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28221, June 21, 1983]

PERMANENT CLOSURE

§ 60.51 License amendment for permanent closure.

(a) DOE shall submit an application to amend the license prior to permanent closure. The submission shall consist of an update of the license application submitted under §§ 60.21 and 60.22, including:

(1) A description of the program for post-permanent closure monitoring of the geologic repository.

(2) A detailed description of the measures to be employed—such as land use controls, construction of monuments, and preservation of records—to regulate or prevent activities that could impair the long-term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for the use of future generations. As a minimum, such measures shall include:

(i) Identification of the controlled area and geologic repository operations area by monuments that have been designed, fabricated, and emplaced to be as permanent as is practicable; and

(ii) Placement of records in the archives and land record systems of local State, and Federal government agencies, and archives elsewhere in the world, that would be likely to be consulted by potential human intruders—such records to identify the location of the geologic repository operations area, including the underground facility, boreholes and shafts, and the boundaries of the controlled area, and the nature and hazard of the waste.

(3) Geologic, geophysical, geochemical, hydrologic, and other site data that are obtained during the operational period pertinent to the long-term isolation of emplaced radioactive wastes.

(4) The results of tests, experiments, and any other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with the host rock, and any other tests, experiments, or analyses pertinent to the long-term isolation of emplaced wastes within the geologic repository.

(5) Any substantial revision of plans for permanent closure.

(6) Other information bearing upon permanent closure that was not available at the time a license was issued.

(b) If necessary, so as to take into account the environmental impact of any substantial changes in the permanent closure activities proposed to be carried out or any significant new information regarding the environmental impacts of such closure, DOE shall also supplement its environmental impact statement and submit such statement, as supplemented, with the application for license amendment.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28221, June 21, 1983; 54 FR 27872, July 3, 1989]

§ 60.52 Termination of license.

(a) Following permanent closure and the decontamination or dismantlement of surface facilities, DOE may apply for an amendment to terminate the license.

(b) Such application shall be filed, and will be reviewed, in accordance with the provisions of § 60.45 and this section.

(c) A license shall be terminated only when the Commission finds with respect to the geologic repository:

(1) That the final disposition of radioactive wastes has been made in conformance with the DOE's plan, as amended and approved as part of the license.

(2) That the final state of the geologic repository operations area conforms to DOE's plans for permanent closure and DOE's plans for the decontamination or dismantlement of surface facilities, as amended and approved as part of the license.

(3) That the termination of the license is authorized by law, including sections 57, 62, and 81 of the Atomic Energy Act, as amended.

[46 FR 13980, Feb. 25, 1981, as amended at 48 FR 28222, June 21, 1983]

Subpart C—Participation by State Governments and Affected Indian Tribes

SOURCE: 51 FR 27164, July 30, 1986, unless otherwise noted.

§ 60.61 Provision of information.

(a) The Director shall provide to the Governor and legislature of any State in which a geologic repository operations area is or may be located, and to the governing body of any affected Indian Tribe, timely and complete information regarding determinations or plans made by the Commission with respect to the site characterization, siting, development, design, licensing, construction, operation, regulation, permanent closure, or decontamination and dismantlement of surface facilities, of such geologic repository operations area.

(b) For purposes of this section, a geologic repository operations area shall be considered to be one which "may be located" in a State if the location thereof in such State has been described in a site characterization plan submitted to the Commission under this part.

(c) Notwithstanding paragraph (a) of this section, the Director is not required to distribute any document to any entity if, with respect to such document, that entity or its counsel is included on a service list prepared pursuant to Part 2 of this chapter.

(d) Copies of all communications by the Director under this section shall be placed in the Public Document Room, and copies thereof shall be furnished to DOE.

§ 60.62 Site review.

(a) Whenever an area has been approved by the President for site characterization, and upon request of a State or an affected Indian Tribe, the Director shall make NRC staff available to consult with representatives of such States and Tribes.

(b) Requests for consultation shall be made in writing to the Director.

(c) Consultation under this section may include:

(1) Keeping the parties informed of the Director's views on the progress of site characterization.

(2) Review of applicable NRC regulations, licensing procedures, schedules, and opportunities for State and Tribe participation in the Commission's regulatory activities.

(3) Cooperation in development of proposals for State and Tribe participation in license reviews.

§ 60.63 Participation in license reviews.

(a) State and local governments and affected Indian Tribes may participate in license reviews as provided in Subpart G of Part 2 of this chapter. A State in which a repository for high level radioactive waste is proposed to be located and any affected Indian Tribe shall have an unquestionable legal right to participate as a party in such proceedings.

(b) In addition, whenever an area has been approved by the President for site characterization, a State or an affected Indian Tribe may submit to the Director a proposal to facilitate its participation in the review of a site characterization plan and/or license application. The proposal may be submitted at any time and shall contain a description and schedule of how the State or affected Indian Tribe wishes to participate in the review, or what services or activities the State or affected Indian Tribe wishes NRC to carry out, and how the services or activities proposed to be carried out by NRC would contribute to such participation. The proposal may include educational or information services (seminars, public meetings) or other actions on the part of NRC, such as establishing additional public document rooms or employment or exchange of State personnel under the Intergovernmental Personnel Act.

(c) The Director shall arrange for a meeting between the representatives of the State or affected Indian Tribe and the NRC staff to discuss any proposal submitted under paragraph (b) of this section, with a view to identifying any modifications that may contribute to the effective participation by such State or Tribe.

(d) Subject to the availability of funds, the Director shall approve all or any part of a proposal, as it may be modified through the meeting described above, if it is determined that:

(1) The proposed activities are suitable in light of the type and magnitude of impacts which the State or affected Indian Tribe may bear;

(2) The proposed activities:

(i) Will enhance communications between NRC and the State or affected Indian Tribe;

(ii) Will make a productive and timely contribution to the review; and

(iii) Are authorized by law.

(e) The Director will advise the State or affected Indian Tribe whether its proposal has been accepted or denied, and if all or any part of proposal is denied, the Director shall state the reason for the denial.

(f) Proposals submitted under this section, and responses thereto, shall be made available at the Public Document Room.

§ 60.64 Notice to States.

If the Governor and legislature of a State have jointly designated on their behalf a single person or entity to receive notice and information from the Commission under this part, the Commission will provide such notice and information to the jointly designated person or entity instead of the Governor and legislature separately.

§ 60.65 Representation.

Any person who acts under this subpart as a representative for a State (or for the Governor or legislature thereof) or for an affected Indian Tribe shall include in the request or other submission, or at the request of the Commission, a statement of the basis of his or her authority to act in such representative capacity.

Subpart D—Records, Reports, Tests, and Inspections

SOURCE: 48 FR 28222, June 21, 1983, unless otherwise noted.

§ 60.71 Records and reports.

(a) DOE shall maintain such records and make such reports in connection with the licensed activity as may be required by the conditions of the license or by rules, regulations, and orders of the Commission as authorized by the Atomic Energy Act and the Energy Reorganization Act.

(b) Records of the receipt, handling, and disposition of radioactive waste at a geologic repository operations area shall contain sufficient information to provide a complete history of the movement of the waste from the shipper through all phases of storage and disposal. DOE shall retain these records in a manner that ensures their useability for future generations in accordance with § 60.51(a)(2).

[48 FR 28222 June 21, 1983, as amended at 53 FR 19251, May 27, 1988]

§ 60.72 Construction records.

(a) DOE shall maintain records of construction of the geologic repository operations area in a manner that ensures their useability for future generations in accordance with § 60.51(a)(2).

(b) The records required under paragraph (a) shall include at least the following:

(1) Surveys of the underground facility excavations, shafts, and boreholes referenced to readily identifiable surface features or monuments;

(2) A description of the materials encountered;

(3) Geologic maps and geologic cross sections;

(4) Locations and amount of seepage;

(5) Details of equipment, methods, progress, and sequence of work;

(6) Construction problems;

(7) Anomalous conditions encountered;

(8) Instrument locations, readings, and analysis;

(9) Location and description of structural support systems;

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

[48 FR 28222 June 21, 1983, as amended at 53 FR 19251, May 27, 1988]

§ 60.73 Reports of deficiencies.

DOE shall promptly notify the Commission of each deficiency found in the characteristics of the site, and design and construction of the geologic repository operations area which, were it to remain uncorrected, could: (a) Be a substantial safety hazard, (b) represent a significant deviation from the design criteria and design bases stated in the application, or (c) represent a deviation from the conditions

stated in the terms of a construction authorization or the license, including license specifications. The notification shall be in the form of a written report, copies of which shall be sent to the Director and to the appropriate Nuclear Regulatory Commission Regional Office listed in Appendix D of Part 20 of this chapter.

§ 60.74 Tests.

(a) DOE shall perform, or permit the Commission to perform, such tests as the Commission deems appropriate or necessary for the administration of the regulations in this part. These may include tests of:

(1) Radioactive waste,

(2) The geologic repository including its structures, systems, and components,

(3) Radiation detection and monitoring instruments, and

(4) Other equipment and devices used in connection with the receipt, handling, or storage of radioactive waste.

(b) The tests required under this section shall include a performance confirmation program carried out in accordance with Subpart F of this part.

§ 60.75 Inspections.

(a) DOE shall allow the Commission to inspect the premises of the geologic repository operations area and adjacent areas to which DOE has rights of access.

(b) DOE shall make available to the Commission for inspection, upon reasonable notice, records kept by DOE pertaining to activities under this part.

(c)(1) DOE shall upon requests by the Director, Office of Nuclear Material Safety and Safeguards, provide rent-free office space for the exclusive use of the Commission inspection personnel. Heat, air-conditioning, light, electrical outlets and janitorial services shall be furnished by DOE. The office shall be convenient to and have full access to the facility and shall provide the inspector both visual and acoustic privacy.

(2) The space provided shall be adequate to accommodate a full-time inspector, a part-time secretary and transient NRC personnel and will be generally commensurate with other office facilities at the geologic repository operations area. A space of 250 square feet either within the geologic repository operations area's office complex or in an office trailer or other onsite space at the geologic repository operations area is suggested as a guide. For locations at which activities are carried out under licenses issued under other parts of this chapter, additional space may be requested to accomodate additional full-time inspectors. The Office space that is provided shall be subject to the approval of the Director, Office of Nuclear Material Safety and Safeguards. All furniture, supplies and communication equipment will be furnished by the Commission.

(3) DOE shall afford any NRC resident inspector assigned to that location, or other NRC inspectors identified by the Regional Administrator as likely to inspect the facility, immediate unfettered access, equivalent to access provided regular employees, following proper identification and compliance with applicable access control measures for security, radiological protection and personal safety.

[48 FR 28222, June 21, 1983, as amended at 52 FR 31612, Aug. 21, 1987]

Subpart E—Technical Criteria

SOURCE: 48 FR 28222, June 21, 1983, unless otherwise noted.

§ 60.101 Purpose and nature of findings.

(a)(1) Subpart B of this part prescribes the standards for issuance of a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area. In particular, § 60.41(c) requires a finding that the issuance of a license will not constitute an unreasonable risk to the health and safety of the public. The purpose of this subpart is to set out performance objectives and site and design criteria which, if satisfied, will support such a finding of no unreasonable risk.

(2) While these performance objectives and criteria are generally stated in unqualified terms, it is not expected that complete assurance that they will be met can be presented. A reasonable assurance, on the basis of the record

before the Commission, that the objectives and criteria will be met is the general standard that is required. For § 60.112, and other portions of this subpart that impose objectives and criteria for repository performance over long times into the future, there will inevitably be greater uncertainties. Proof of the future performance of engineered barrier systems and the geologic setting over time periods of many hundreds or many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with those objectives and criteria. Demonstration of compliance with such objectives and criteria will involve the use of data from accelerated tests and predictive models that are supported by such measures as field and laboratory tests, monitoring data and natural analog studies.

(b) Subpart B of this part also lists findings that must be made in support of an authorization to construct a geologic repository operations area. In particular, § 60.31(a) requires a finding that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository operations area of the design proposed without unreasonable risk to the health and safety of the public. As stated in that paragraph, in arriving at this determination, the Commission will consider whether the site and design comply with the criteria contained in this subpart. Once again, while the criteria may be written in unqualified terms, the demonstration of compliance may take uncertainties and gaps in knowledge into account, provided that the Commission can make the specified finding of reasonable assurance as specified in paragraph (a) of this section.

§ 60.102 Concepts.

This section provides a functional overview of Subpart E. In the event of any inconsistency with definitions found in § 60.2, those definitions shall prevail.

(a) *The HLW facility.* NRC exercises licensing and related regulatory authority over those facilities described in section 202 (3) and (4) of the Energy Reorganization Act of 1974. Any of these facilities is designated a *HLW facility.*

(b) *The geologic repository operations area.* (1) This part deals with the exercise of authority with respect to a particular class of HLW facility—namely a *geologic repository operations area.*

(2) *A geologic repository operations area* consists of those surface and subsurface areas that are part of a geologic repository where radioactive waste handling activities are conducted. The underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals, is designated the *underground facility.*

(3) The exercise of Commission authority requires that the geologic repository operations area be used for *storage* (which includes *disposal*) of *high-level radioactive wastes (HLW).*

(4) HLW includes irradiated reactor fuel as well as reprocessing wastes. However, if DOE proposes to use the geologic repository operations area for storage of *radioactive waste* other than HLW, the storage of this radioactive waste is subject to the requirements of this part.

(c) *Areas related to isolation.* Although the activities subject to regulation under this part are those to be carried out at the geologic repository operations area, the licensing process also considers characteristics of adjacent areas that are defined in other ways. There is to be an area surrounding the underground facility referred to above, which is designated the *controlled area,* within which DOE is to exercise specified controls to prevent adverse human actions following permanent closure. The location of the controlled area is the *site.* The *accessible environment* is the atmosphere, land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area. There is an area, designated the *geologic setting,* which includes the geo-

logic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located. The geologic repository operations area plus the portion of the geologic setting that provides isolation of the radioactive waste make up the *geologic repository.*

(d) *Stages in the licensing process.* There are several stages in the licensing process. The *site characterization* stage, though begun before submission of a license application, may result in consequences requiring evaluation in the license review. The *construction stage* would follow, after issuance of a construction authorization. A *period of operations* follows the issuance of a license by the Commission. The period of operations includes the time during which *emplacement* of wastes occurs; any subsequent period before permanent closure during which the emplaced wastes are *retrievable;* and *permanent closure,* which includes sealing of shafts. Permanent closure represents the end of active human intervention with respect to the engineered barrier system.

(e) *Isolation of waste.* (1) During the first several hundred years following permanent closure of a geologic repository, when radiation and thermal levels are high and the uncertainties in assessing repository performance are large, special emphasis is placed upon the ability to contain the wastes by waste packages within an *engineered barrier system.* This is known as the *containment period.* The *engineered barrier system* includes the waste packages and the underground facility. A *waste package* is composed of the waste form and any containers, shielding, packing, and absorbent materials immediately surrounding an individual waste container. The *underground facility* means the underground structure, including openings and backfill materials, but excluding, shafts, boreholes, and their seals.

(2) Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. The engineered barrier system works to control the release of radioactive material to the geologic setting and the geologic setting works to control the release c radioactive material to the accessibl environment. *Isolation* means inhibi ing the transport of radioactive mat rial so that amounts and concentr tions of the materials entering the a cessible environment will be kep within prescribed limits.

Performance Objectives

§ 60.111 Performance of the geologic r pository operations area through pe manent closure.

(a) *Protection against radiation e posures and releases of radioactiv material.* The geologic repository op erations area shall be designed so tha until permanent closure has been com pleted, radiation exposures and radi ation levels, and releases of radioactiv materials to unrestricted areas, will a all times be maintained within th limits specified in Part 20 of this chap ter and such generally applicable envi ronmental standards for radioactivit as may have been established by th Environmental Protection Agency.

(b) *Retrievability of waste.* (1) Th geologic repository operations are shall be designed to preserve th option of waste retrieval throughou the period during which wastes ar being emplaced and, thereafter, unti the completion of a preformance con firmation program and Commissio review of the information obtaine from such a program. To satisfy thi objective, the geologic repository oper ations area shall be designed so tha any or all of the emplaced waste coul be retrieved on a reasonable schedul starting at any time up to 50 year after waste emplacement operation are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§ 60.112 Overall system performance objective for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure.

(a) *General provisions*—(1) *Engineered barrier system.* (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analysed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in § 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) *Geologic setting.* The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement groundwater travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are:

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and groundwater; and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

LAND OWNERSHIP AND CONTROL

§ 60.121 Requirements for ownership and control of interests in land.

(a) *Ownership of land.* (1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use.

(2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) Rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Additional controls.* Appropriate controls shall be established outside of the controlled area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) *Water rights.* (1) DOE shall also have obtained such water rights as may be needed to accomplish the purpose of the geologic repository operations area.

(2) Water rights are included in the additional controls to be established under paragraph (b) of this section.

SITING CRITERIA

§ 60.122 Siting criteria.

(a)(1) A geologic setting shall exhibit an appropriate combination of the conditions specified in paragraph (b) of this section so that, together with the engineered barriers system, the f vorable conditions present are suf cient to provide reasonable assuran that the performance objectives rel ing to isolation of the waste will met.

(2) If any of the potentially adver conditions specified in paragraph (of this section is present, it may co promise the ability of the geologic pository to meet the performance o jectives relating to isolation of t waste. In order to show that a pote tially adverse condition does not compromise the performance of t geologic repository the following mu be demonstrated:

(i) The potentially adverse hum activity or natural condition has be adequately investigated, including t extent to which the condition may present and still be undetected taki into account the degree of resoluti achieved by the investigations; and

(ii) The effect of the potentially a verse human activity or natural con tion on the site has been adequate evaluated using analyses which a sensitive to the potentially adver human activity or natural conditi and assumptions which are not like to underestimate its effect; and

(iii)(A) The potentially adver human activity or natural condition shown by analysis pursuant to par graph (a)(2)(ii) of this section not affect significantly the ability of t geologic repository to meet the pe formance objectives relating to isol tion of the waste, or

(B) The effect of the potentially a verse human activity or natural con tion is compensated by the presence a combination of the favorable chara teristics so that the performance o jectives relating to isolation of t waste are met, or

(C) The potentially adverse huma activity or natural condition can remedied.

(b) *Favorable conditions.* (1) Th nature and rates of tectonic, hydroge logic, geochemical, and geomorph processes (or any of such processe operating within the geologic settin during the Quaternary Period, whe projected, would not affect or woul favorably affect the ability of the ge logic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide:

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and immediately surrounding hydrogeologic units; and

(iii) Low vertical permeability and low hydraulic gradient between the host rock and the surrounding hydrogeologic units.

(3) Geochemical conditions that:

(i) Promote precipitation or sorption of radionuclides;

(ii) Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or

(iii) Inhibit the transport of radionuclides by particulates, colloids, and complexes.

(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(6) A low population density within the geologic setting and a controlled area that is remote from population centers.

(7) Pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years.

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide—

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units;

(ii) A water table sufficiently below the underground facility such that fully saturated voids contiguous with the water table do not encounter the underground facility;

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility;

(iv) A host rock that provides for free drainage; or

(v) A climatic regime in which the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration.

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of

Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(9) Groundwater conditions in the host rock that are not reducing.

(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

(15) Evidence of igneous activity since the start of the Quaternary Period.

(16) Evidence of extreme erosion during the Quaternary Period.

(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(18) Evidence of subsurface mining for resources within the site.

(19) Evidence of drilling for any purpose within the site.

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

(22) Potential for the water table to rise sufficiently so as to cause saturation of an underground facility located in the unsaturated zone.

(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

[48 FR 28222, June 21, 1983, as amended at 50 FR 29647, July 22, 1985]

Design Criteria for the Geologic Repository Operations Area

§ 60.130 Scope of design criteria for the geologic repository operations area.

Sections 60.131 through 60.134 specify minimum criteria for the design of the geologic repository operations area. These design criteria are not intended to be exhaustive, however. Omissions in §§ 60.131 through 60.134 do not relieve DOE from any obligation to provide such safety features in a specific facility needed to achieve the performance objectives. All design bases must be consistent with the results of site characterization activities.

§ 60.131 General design criteria for the geologic repository operations area.

(a) *Radiological protection.* The geologic repository operations area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in restricted areas within the limits specified in Part 20 of this chapter. Design shall include:

(1) Means to limit concentrations of radioactive material in air;

(2) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and

providing adequate space for ease of operation;

(3) Suitable shielding;

(4) Means to monitor and control the dispersal of radioactive contamination;

(5) Means to control access to high radiation areas or airborne radioactivity areas; and

(6) A radiation alarm system to warn of significant increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability.

(b) *Structures, systems, and components important to safety*—(1) *Protection against natural phenomena and environmental conditions.* The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

(2) *Protection against dynamic effects of equipment failure and similar events.* The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts, that could result from equipment failure, and similar events and conditions that could lead to loss of their safety functions.

(3) *Protection against fires and explosions.* (i) The structures, systems, and components important to safety shall be designed to perform their safety fuctions during and after credible fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

(4) *Emergency capability.* (i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(5) *Utility services.* (i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and accident conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(iii) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely emergency power can be provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety.

(6) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(7) *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to

nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions The calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(8) *Instrumentation and control systems.* The design shall include provisions for instrumentation and control systems to monitor and control the behavior of systems important to safety over anticipated ranges for normal operation and for accident conditions.

(9) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

(10) *Shaft conveyances used in radioactive waste handling.* (i) Hoists important to safety shall be designed to preclude cage free fall.

(ii) Hoists important to safety shall be designed with a reliable cage location system.

(iii) Loading and unloading systems for hoists important to safety shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(iv) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place and ready for transfer.

§ 60.132 Additional design criteria for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111(a).

(c) *Radiation control and monitoring*—(1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objectives of § 60.111(a).

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.

§ 60.133 Additional design criteria for the underground facility.

(a) *General criteria for the underground facility.* (1) The orientation, geometry, layout, and depth of the underground facility, and the design of

any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(2) The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as flooding, fires and explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Retrieval of waste.* The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of § 60.111.

(d) *Control of water and gas.* The design of the underground facility shall provide for control of water or gas intrusion.

(e) *Underground openings.* (1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) *Rock excavation.* The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater to contact the waste packages or radionuclide migration to the accessible environment.

(g) *Underground facility ventilation.* The ventilation system shall be designed to:

(1) Control the transport of radioactive particulates and gases within and releases from the underground facility in accordance with the performance objectives of § 60.111(a),

(2) Assure continued function during normal operations and under accident conditions; and

(3) Separate the ventilation of excavation and waste emplacement areas.

(h) *Engineered barriers.* Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

(i) *Thermal loads.* The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, and surrounding strata, groundwater system.

[48 FR 28222, June 21, 1983, as amended at 50 FR 29648, July 22, 1985]

§ 60.134 Design of seals for shafts and boreholes.

(a) *General design criterion.* Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives or the period following permanent closure.

(b) *Selection of materials and placement methods.* Materials and placement methods for seals shall be selected to reduce, to the extent practicable:

(1) The potential for creating a preferential pathway for groundwater to contact the waste packages or

(2) For radionuclide migration through existing pathways.

[48 FR 28222, June 21, 1983, as amended at 50 FR 29648, July 22, 1985]

Design Criteria for the Waste Package

§ 60.135 Criteria for the waste package and its components.

(a) *High-level-waste package design in general.* (1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire

and explosion hazards, thermal loads, and synergistic interactions.

(b) *Specific criteria for HLW package design*—(1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials in an amount that could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives.

(2) *Free liquids.* The waste package shall not contain free liquids in an amount that could compromise the ability of the waste packages to achieve the performance objectives relating to containment of HLW (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure.

(3) *Handling.* Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) *Unique identification.* A label or other means of identification shall be provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

(c) Waste form criteria for HLW. High-level radioactive waste that is emplaced in the underground facility shall be designed to meet the following criteria:

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall be consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) *Combustibles.* All combustible radioactive wastes shall be reduced to a noncombustible form unless it can be demonstrated that a fire involving the waste packages containing combustibles will not compromise the integrity of other waste packages, adversely affect any structures, systems, or components important to safety, or compromise the ability of the underground facility to contribute to waste isolation.

(d) *Design criteria for other radioactive wastes.* Design criteria for waste types other than HLW will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository.

Performance Confirmation Requirements

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

Subpart F—Performance Confirmation Program

Source: 48 FR 28228, June 21, 1983, unless otherwise noted.

§ 60.140 General requirements.

(a) The performance confirmation program shall provide data which indicates, where practicable, whether:

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The program shall be implemented so that:

(1) It does not adversely affect the ability of the natural and engineered

elements of the geologic repository to meet the performance objectives.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the geologic repository operations area for monitoring the condition of the waste packages. Waste packages chosen for the program shall be representative of those to be emplaced in the underground facility.

(b) Consistent with safe operation at the geologic repository operations area, the environment of the waste packages selected for the waste package monitoring program shall be representative of the environment in which the wastes are to be emplaced.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the underground facility during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

Subpart G—Quality Assurance

SOURCE: 48 FR 28228, June 21, 1983, unless otherwise noted.

§ 60.150 Scope.

As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the geologic repository and its subsystems or components will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety, to design and characterization of barriers important to waste isolation and to activities related thereto. These activities include: site characterization, facility and equipment construction, facility operation, performance confirmation, permanent closure, and decontamination and dismantling of surface facilities.

§ 60.152 Implementation.

DOE shall implement a quality assurance program based on the criteria of Appendix B of 10 CFR Part 50 as applicable, and appropriately supplemented by additional criteria as required by § 60.151.

Subpart H—Training and Certification of Personnel

SOURCE: 48 FR 28229, June 21, 1983, unless otherwise noted.

§ 60.160 General requirements.

Operations of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety must also be certified in such operations.

§ 60.161 Training and certification program.

DOE shall establish a program for training, proficiency testing, certification and requalification of operating and supervisory personnel.

§ 60.162 Physical requirements.

The physical condition and the general health of personnel certified for operations that are important to safety shall not be such as might cause operational errors that could endanger the public health and safety. Any condition which might cause impaired judgment or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, so long as appropriate provisions are made to accommodate such conditions.

Subpart I—Emergency Planning Criteria [Reserved]

PART 61—LICENSING REQUIREMENTS FOR LAND DISPOSAL OF RADIOACTIVE WASTE

Subpart A—General Provisions

Sec.

Subpart B—Licenses

Appendix C

American Arbitration Association. The two arbitrators thus selected shall name a third arbitrator within thirty (30) days of their first meeting. In the event of their failure to so name such third arbitrator, that arbitrator shall be named as provided in the Commercial Arbitration Rules of the American Arbitration Association. The third arbitrator shall act as chairperson of the panel. The arbitration shall be governed by the Commercial Arbitration Rules of the American Arbitration Association. The arbitration shall be limited to the issue submitted. The panel of arbitrators shall not rewrite, change, or amend these General Regulations or the Contracts of any of the parties to the dispute. The panel of arbitrators shall render a final decision in this dispute within sixty (60) days after the date of the naming of the third arbitrator. A decision of any two of the three arbitrators named to the panel shall be final and binding on all parties involved in the dispute.

§ 904.14 Future regulations.

(a) Western may from time to time promulgate such additional or amendatory regulations as deemed necessary for the administration of the Project in accordance with applicable law; *Provided*, That no right under any Contract shall be impaired or obligation thereunder be extended thereby.

(b) Any modification, extension, or waiver of any provision of these General Regulations granted for the benefit of any one or more Contractors shall not be denied to any other Contractor.

(c) Western reserves the right to terminate, modify, or extend these regulations, either partially or in their entirety, to the extent permitted by law or existing contract.

PART 960—GENERAL GUIDELINES FOR THE RECOMMENDATION OF SITES FOR NUCLEAR WASTE REPOSITORIES

Subpart A—General Provisions

Sec.

Subpart B—Implementation Guidelines

Subpart C—Postclosure guidelines

Subpart D—Preclosure Guidelines

PRECLOSURE RADIOLOGICAL SAFETY

AUTHORITY: The Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.); Energy Reorganization Act of 1974 (42 U.S.C. 5801 et seq.); Department of Energy Organization Act of 1977 (42 U.S.C. 7101 et seq.); Nuclear Waste Policy Act of 1982 (Pub. L. 97-425, 96 Stat. 2201).

SOURCE: 49 FR 47752, Dec. 6, 1984, unless otherwise noted.

Subpart A—General Provisions

§ 960.1 Applicability.

These guidelines were developed in accordance with the requirements of Section 112(a) of the Nuclear Waste Policy Act of 1982 for use by the Secretary of Energy in evaluating the suitability of sites for the development of repositories. The guidelines will be used for suitability evaluations and determinations made pursuant to Section 112(b) and any preliminary suitability determinations required by Section 114(f). The guidelines set forth in this Part are intended to complement the requirements set forth in the Act, 10 CFR Part 60, and 40 CFR Part 191. The DOE recognizes NRC jurisdiction for the resolution of differences between the guidelines and 10 CFR Part 60. The guidelines have received the concurrence of the NRC. The DOE contemplates revising the guidelines from time to time, as permitted by the Act, to take into account revisions made to the above regulations and to otherwise update the guidelines as necessary. The DOE will submit the revisions to the NRC and obtain its concurrence before issuance.

§ 960.2 Definitions.

As used in this part:

"Accessible environment" means the atmosphere, the land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area.

"Act" means the Nuclear Waste Policy Act of 1982.

"Active fault" means a fault along which there is recurrent movement, which is usually indicated by small, periodic displacements or seismic activity.

"Affected area" means either the area of socioeconomic impact or the area of environmental impact, each of which will vary in size among potential repository sites.

"Affected Indian tribe" means any Indian tribe (1) within whose reservation boundaries a repository for radioactive waste is proposed to be located or (2) whose federally defined possessory or usage rights to other lands outside the reservation's boundaries arising out of congressionally ratified treaties may be substantially and adversely affected by the locating of such a facility: *Provided,* That the Secretary of the Interior finds, upon the petition of the appropriate governmental officials of the tribe, that such effects are both substantial and adverse to the tribe.

"Affected State" means any State that (1) has been notified by the DOE in accordance with Section 116(a) of the Act as containing a potentially acceptable site; (2) contains a candidate site for site characterization or repository development; or (3) contains a site selected for repository development.

"Application" means the act of making a finding of compliance or noncompliance with the qualifying or disqualifying conditions specified in the guidelines of Subparts C and D, in

accordance with the types of findings specified in Appendix III.

"Aquifer" means a formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

"Barrier" means any material or structure that prevents or substantially delays the movement of water or radionuclides.

"Candidate site" means an area, within a geohydrologic setting, that is recommended by the Secretary of Energy under Section 112 of the Act for site characterization, approved by the President under Section 112 of the Act for characterization, or undergoing site characterization under Section 113 of the Act.

"Closure" means final backfilling of the remaining open operational areas of the underground facility and boreholes after the termination of waste emplacement, culminating in the sealing of shafts.

"Confining unit" means a body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Controlled area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be prohibited before and after permanent closure.

"Cumulative releases of radionuclides" means the total number of curies of radionuclides entering the accessible environment in any 10,000-year period, normalized on the basis of radiotoxicity in accordance with 40 CFR Part 191. The peak cumulative release of radionuclides refers to the 10,000-year period during which any such release attains its maximum predicted value.

"Decommissioning" means the permanent removal from service of surface facilities and components necessary for preclosure operations only, after repository closure, in accordance with regulatory requirements and environmental policies.

"Determination" means a decision by the Secretary that a site is suitable for site characterization for the selection of a repository site or that a site is suitable for the development of a repository, consistent with applications of the guidelines of Subparts C and D in accordance with the provisions set forth in Subpart B.

"Disposal" means the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the isolation of such waste from the accessible environment.

"Disqualifying condition" means a condition that, if present at a site, would eliminate that site from further consideration.

"Disturbed zone" means that portion of the controlled area, excluding shafts, whose physical or chemical properties are predicted to change as a result of underground facility construction or heat generated by the emplaced radioactive waste such that the resultant change of properties could have a significant effect on the preformance of the geologic repository.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Effective porosity" means the amount of interconnected pore space and fracture openings available for the transmission of fluids, expressed as the ratio of the volume of interconnected pores and openings to the volume of rock.

"Engineered-barrier system" means the manmade components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. Such term includes the radioactive-waste form, radioactive-waste canisters, materials placed over and around such canisters, any other components of the waste package, and barriers used to seal penetrations in and into the underground facility.

"Environmental assessment" means the document required by Section 112(b)(1)(E) of the Nuclear Waste Policy Act of 1982.

"Environmental impact statement" means the document required by Section 102(2)(C) of the National Environmental Policy Act of 1969. Sections 114(a) and 114(f) of the Nuclear Waste Policy Act of 1982 include certain limitations on the National Environmental Policy Act requirements as they apply to the preparation of an environmental impact statement for the development of a repository at a characterized site.

"EPA" means the U.S. Environmental Protection Agency or its duly authorized representatives.

"Evaluation" means the act of carefully examining the characteristics of a site in relation to the requirements of the qualifying or disqualifying conditions specified in the guidelines of Subparts C and D. Evaluation includes the consideration of favorable and potentially adverse conditions.

"Excepted" means assumed to be probable or certain on the basis of existing evidence and in the absence of significant evidence to the contrary.

"Expected repository performance" means the manner in which the repository is predicted to function, consideration those conditions, processes, and events that are likely to prevail or may occur during the time period of interest.

"Facility" means any structure, system, or system component, including engineered barriers, created by the DOE to meet repository-performance or functional objectives.

"Fault" means a fracture or a zone of fractures along which there has been displacement of the side relative to one another parallel to the fracture or zone of fractures.

"Faulting" means the process of fracturing and displacement that produces a fault.

"Favorable condition" means a condition that, though not necessary to qualify a site, is presumed, if present, to enhance confidence that the qualifying condition of a particular guideline can be met.

"Finding" means a conclusion that is reached after evaluation.

"Geohydrologic setting" means the system of geohydrologic units that is located within a given geologic setting.

"Geohydrologic system" means the geohydrologic units within a geologic setting, including any recharge, discharge, interconnections between units, and any natural or man-induced processes or events that could affect ground-water flow within or among those units.

"Geohydrologic unit" means an aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system.

"Geologic repository" means a system, requiring licensing by the NRC, that is intended to be used, or may be used, for the disposal of radioactive waste in excavated geologic media. A geologic repository includes (1) the geologic-repository operations area and (2) the portion of the geologic setting that provides isolation of the radioactive waste and is located within the controlled area.

"Geologic-repository operations area" means a radioactive-waste facility that is part of the geologic repository, including both surface and subsurface areas and facilities where waste-handling activities are conducted.

"Geologic setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic-repository operations area is or may be located.

"Geomorphic processes" means geologic processes that are responsible for the general configuration of the Earth's surface, including the development of present landforms and their relationships to underlying structures, and are responsible for the geologic changes recorded by these surface features.

"Ground water" means all subsurface water as distinct from surface water.

"Ground-water flux" means the rate of ground-water flow per unit area of porous or fractured media measured perpendicular to the direction of flow.

"Ground-water sources" means aquifers that have been or could be economically and technologically de-

veloped as sources of water in the foreseeable future.

"Ground-water travel time" means the time required for a unit volume of ground water to travel between two locations. The travel time is the length of the flow path divided by the velocity, where velocity is the average ground-water flux passing through the cross-sectional area of the geologic medium through which flow occurs, perpendicular to the flow direction, divided by the effective porosity along the flow path. If discrete segments of the flow path have different hydrologic properties, the total travel time will be the sum of the travel times for each discrete segment.

"Guideline" means a statement of policy or procedure that may include, when appropriate, qualifying, disqualifying, favorable, or potentially adverse conditions as specified in the "guidelines."

"Guidelines" means Part 960 of Title 10 of the Code of Federal Regulations—General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories.

"High-level radioactive waste" means (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and (2) other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation.

"Highly populated area" means any incoporated place (recognized by the decennial reports of the U.S. Bureau of the Census) of 2,500 or more persons, or any census designated place (as defined and delineated by the Bureau) of 2,500 or more persons, unless it can be demonstrated that any such place has a lower population density than the mean value for the continental United States. Counties or county equivalents, whether incorporated or not, are specifically excluded form the definition of "place" as used herein.

"Host rock" means the geologic medium in which the waste is emplaced, specifically the geologic materials that directly encompass and are in close proximity to the underground facility.

"Hydraulic conductivity" means the volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

"Hydraulic gradient" means a change in the static pressure of ground water, expressed in terms of the height of water above a datum, per unit of distance in a given direction.

"Hydrologic process" means any hydrologic phenomenon that exhibits a continuous change in time, whether slow or rapid.

"Hydrologic properties" means those properties of a rock that govern the entrance of water and the capacity to hold, transmit, and deliver water, such as porosity, effective porosity, specific retention, permeability, and the directions of maximum and minimum permeabilities.

"Igneous activity" means the emplacement (intrusion) of molten rock material (magma) into material in the Earth's crust or the expulsion (extrusion) of such material onto the Earth's surface or into its atmosphere or surface water.

"Isolation" means inhibiting the transport of radioactive material so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

"Likely" means processing or displaying the qualities, characteristics, or attributes that provide a reasonable basis for confidence that what is expected indeed exists or will occur.

"Lithosphere" means the solid part of the Earth, including any ground water contained within it.

"Member of the public" means any individual who is not engaged in operations involving the management, storage, and disposal of radioactive waste. A worker so engaged is a member of the public except when on duty at the geologic-repository operations area.

"Mitigation" means: (1) Avoiding the impact altogether by not taking a certain action or parts of an action; (2)

minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; or (5) compensating for the impact by replacing or providing substitute resources or environments.

"Model" means a conceptual description and the associated mathematical representation of a system, subsystem, component, or condition that is used to predict changes from a baseline state as a function of internal and/or external stimuli and as a function of time and space.

"NRC" means the U.S. Nuclear Regulatory Commission or its duly authorized representatives.

"Perched ground water" means unconfined ground water separated from an underlying body of ground water by an unsaturated zone. Its water table is a perched water table. Perched ground water is held up by a perching bed whose permeability is so low that water percolating downward through it is not able to bring water in the underlying unsaturated zone above atmospheric pressure.

"Performance assessment" means any analysis that predicts the behavior of a system or system component under a given set of constant and/or transient conditions. Performance assessments will include estimates of the effects of uncertainties in data and modeling.

"Permanent closure" is synonymous with "closure."

"Postclosure" means the period of time after the closure of the geologic repository.

"Potentially acceptable site" means any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the DOE undertakes preliminary drilling and geophysical testing for the definition of site location.

"Potentially adverse condition" means a condition that is presumed to detract from expected system performance, but further evaluation, additional data, or the identification of compensating or mitigating factors may indicate that its effect on the expected system performance is acceptable.

"Preclosure" means the period of time before and during the closure of the geologic repository.

"Pre-waste-emplacement" means before the authorization of repository construction by the NRC.

"Qualifying condition" means a condition that must be satisfied for a site to be considered acceptable with respect to a specific guideline.

"Quaternary Period" means the second period of the Cenozoic Era, following the Tertiary, beginning 2 to 3 million years ago and extending to the present.

"Radioactive waste" or "waste" means high-level radioactive waste and other radioactive materials, including spent nuclear fuel, that are received for emplacement in a geologic repository.

"Radioactive-waste facility" means a facility subject to the licensing and related regulatory authority of the NRC pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat. 1244).

"Radionuclide retardation" means the process or processes that cause the time required for a given radionuclide to move between two locations to be greater than the ground-water travel time, because of physical and chemical interactions between the radionuclide and the geohydrologic unit through which the radionuclide travels.

"Reasonably available technology" means technology which exists and has been demonstrated or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time period.

"Repository" is synonymous with "geologic repository."

"Repository closure" is synonymous with "closure."

"Repository construction" means all excavation and mining activities associated with the construction of shafts, shaft stations, rooms, and necessary openings in the underground facility, preparatory to radioactive-waste emplacement, as well as the construction

of necessary surface facilities, but excluding site-characterization activities.

"Repository operation" means all of the functions at the site leading to and involving radioactive-waste emplacement in the underground facility, including receiving, transportation, handling, emplacement, and, if necessary, retrieval.

"Repository support facilities" means all permanent facilities constructed in support of site-characterization activities and repository construction, operation, and closure activities, including surface structures, utility lines, roads, railroads, and similar facilities, but excluding the underground facility.

"Restricted area" means any area access to which is controlled by the DOE for purposes of protecting individuals from exposure to radiation and radioactive materials before repository closure, but not including any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

"Retrieval" means the act of intentionally removing radioactive waste before repository closure from the underground location at which the waste had been previously emplaced for disposal.

"Saturated zone" means that part of the Earth's crust beneath the water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

"Secretary" means the Secretary of Energy.

"Site" means a potentially acceptable site or a candidate site, as appropriate, until such time as the controlled area has been established, at which time the site and the controlled area are the same.

"Site characterization" means activities, whether in the laboratory or in the field, undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken.

"Siting" means the collection of exploration, testing, evaluation, and decision-making activities associated with the process of site screening, site nomination, site recommendation, and site approval for characterization or repository development.

"Source term" means the kinds and amounts of radionuclides that make up the source of a potential release of radioactivity.

"Spent nuclear fuel" means fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

"Surface facilities" means repository support facilities within the restricted area.

"Surface water" means any waters on the surface of the Earth, including fresh and salt water, ice, and snow.

"System" means the geologic setting at the site, the waste package, and the repository, all acting together to contain and isolate the waste.

"System performance" means the complete behavior of a repository system in response to the conditions, processes, and events that may affect it.

"Tectonic" means of, or pertaining to, the forces involved in, or the resulting structures or features of, "tectonics."

"Tectonics" means the branch of geology dealing with the broad architecture of the outer part of the Earth, that is, the regional assembling of structural or deformational features and the study of their mutual relations, origin, and historical evolution.

"To the extent practicable" means the degree to which an intended course of action is capable of being effected in a manner that is reasonable and feasible within a framework of constraints.

"Underground facility" means the underground structure and the rock required for support, including mined openings and backfill materials, but excluding shafts, boreholes, and their seals.

"Unsaturated zone" means the zone between the land surface and the water table. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric.

"Waste form" means the radioactive waste materials and any encapsulating or stabilizing matrix.

"Waste package" means the waste form and any containers, shielding, packing, and other sorbent materials immediately surrounding an individual waste container.

"Water table" means that surface in a body of ground water at which the water pressure is atmospheric.

Subpart B—Implementation Guidelines

§ 960.3 Implementation guidelines.

The guidelines of this subpart establish the procedure and basis for applying the postclosure and the preclosure guidelines of Subparts C and D, respectively, to evaluations of the suitability of sites for the development of repositories. As may be appropriate during the siting process, this procedure requires consideration of a variety of geohydrologic settings and rock types, regionality, and environmental impacts and consultation with affected States, affected Indian tribes, and Federal agencies.

§ 960.3-1 Siting provisions.

The siting provisions establish the framework for the implementation of the siting process specified in § 960.3-2. Sections 960.3-1-1 and 960.3-1-2 require that consideration be given to sites situated in different geohydrologic settings and different types of host rock, respectively. These diversity guidelines are intended to balance the process of site selection by requiring consideration of a variety of geologic conditions and media, and thereby enhance confidence in the technical suitability of sites selected for the development of repositories. As required by the Act, § 960.3-1-3 specifies consideration of a regional distribution of repositories after recommendation of a site for development of the first repository. Section 960.3-1-4 describes the evidence that is required to support siting decisions. Section 960.3-1-5 establishes the basis for site evaluations against the postclosure and the preclosure guidelines of Subparts C and D during the various phases of the siting process.

§ 960.3-1-1 Diversity of geohydrologic settings.

Consideration shall be given to a variety of geohydrologic settings in which sites for the development of repositories may be located. To the extent practicable, sites recommended as candidate sites for characterization shall be located in different geohydrologic settings.

§ 960.3-1-2 Diversity of rock types.

Consideration shall be given to a variety of geologic media in which sites for the development of repositories may be located. To the extent practicable, and with due consideration of candidate sites characterized previously or approved for such characterization if the circumstances apply, sites recommended as candidate sites for characterization shall have different types of host rock.

§ 960.3-1-3 Regionality.

In making site recommendations for repository development after the site for the first repository has been recommended, the Secretary shall give due consideration to the need for, and the advantages of, a regional distribution in the siting of subsequent repositories. Such consideration shall take into account the proximity of sites to locations at which waste is generated or temporarily stored and at which other repositories have been or are being developed.

§ 960.3-1-4 Evidence for siting decisions.

The siting process involves a sequence of four decisions: The identification of potentially acceptable sites; the nomination of sites as suitable for characterization; the recommendation of sites as candidate sites for site characterization; and after the completion

of site characterization and nongeologic data gathering, the recommendation of a candidate site for the development of a repository. Each of these decisions will be supported by the evidence specified below.

§ 960.3-1-4-1 Site identification as potentially acceptable.

The evidence for the identification of a potentially acceptable site shall be the types of information specified in Appendix IV of this part. Such evidence will be relatively general and less detailed than that required for the nomination of a site as suitable for characterization. Because the gathering of detailed geologic data will not take place until after the recommendation of a site for characterization, the levels of information may be relatively greater for the evaluation of those guidelines in Subparts C and D that pertain to surface-identifiable factors for such site. The sources of information shall include the literature in the public domain and the private sector, when available, and will be supplemented in some instances by surface investigations and conceptual engineering design studies conducted by the DOE. Geologic surface investigations may include the mapping of identifiable rock masses, fracture and joint characteristics, and fault zones. Other surface investigations will consider the aquatic and terrestrial ecology; water rights and uses; topography; potential offsite hazards; natural resource concentrations; national or State protected resources; existing transportation systems; meteorology and climatology; population densities, centers, and distributions; and general socioeconomic characteristics.

§ 960.3-1-4-2 Site nomination for characterization.

The evidence required to support the nomination of a site as suitable for characterization shall include the types of information specified in Appendix IV of this part and shall be contained or referenced in the environmental assessments to be prepared in accordance with the requirements of the Act. The source of this information shall include the literature and related studies in the public domain and the private sector, when available, and various meteorological, environmental, socioeconomic, and transportation studies conducted by the DOE in the affected area; exploratory boreholes in the region of such site, including lithologic logging and hydrologic and geophysical testing of such boreholes, laboratory testing of core samples for the evaluation of geochemical and engineering rock properties, and chemical analyses of water samples from such boreholes; surface investigations, including geologic mapping and geophysical surveys, and compilations of satellite imagery data; in situ or laboratory testing of similar rock types under expected repository conditions; evaluations of natural and man-made analogs of the repository and its subsystems, such as geothermally active areas, underground excavations, and case histories of socioeconomic cycles in areas that have experienced intermittent large-scale construction and industrial activities; and extrapolations of regional data to estimate site-specific characteristics and conditions. The exact types and amounts of information to be collected within the above categories, including such details as the specific types of hydrologic tests, combinations of geophysical tests, or number of exploratory boreholes, are dependent on the site-specific needs for the application of the guidelines of Subparts C and D, in accordance with the provisions of this Subpart and the application requirements set forth in Appendix III of this part. The evidence shall also include those technical evaluations that use the information specified above and that provide additional bases for evaluating the ability of a site to meet the qualifying conditions of the guidelines of Subparts C and D. In developing the above-mentioned bases for evaluation, as may be necessary, assumptions that approximate the characteristics or conditions considered to exist at a site, or expected to exist or occur in the future, may be used. These assumptions will be realistic but conservative enough to underestimate the potential for a site to meet the qualifying condition of a guideline; that is, the use of such assumptions should not lead to an exaggeration of the

ability of a site to meet the qualifying condition.

§ 960.3-1-4-3 Site recommendation for characterization.

The evidence required to support the recommendation of a site as a candidate site for characterization shall consist of the evaluations and data contained or referenced in the environmental assessment for such site, unless the Secretary certifies that such information, in the absence of additional preliminary borings or excavations, will not be adequate to satisfy applicable requirements of the Act.

§ 960.3-1-4-4 Site recommendation for repository development.

The evidence required to support the recommendation of a candidate site for the development of a repository, after the completion of characterization activities at such site, shall consist of the information specified in Section 114(a) of the Act for the comprehensive statement of the basis for such recommendation and Section 114(f) of the Act for the environmental impact statement. This evidence shall be obtained by the characterization of such site, according to the requirements specified in Section 113(b) of the Act and in 10 CFR 60.11, and by nongeologic data gathering.

§ 960.3-1-5 Basis for site evaluations.

Evaluations of individual sites and comparisons between and among sites shall be based on the postclosure and preclosure guidelines specified in Subparts C and D, respectively. Except for screening for potentially acceptable sites as specified in § 960.3-2-1, such evaluations shall place *primary significance* on the postclosure guidelines and *secondary significance* on the preclosure guidelines, with each set of guidelines considered collectively for such purposes. Both the postclosure and the preclosure guidelines consist of a system guideline or guidelines and corresponding groups of technical guidelines. The postclosure guidelines of Subpart C contain eight technical guidelines in one group. The preclosure guidelines of Subpart D contain eleven technical guidelines separated into three groups that represent, *in decreasing order of importance*, preclosure radiological safety; environment, socioeconomics, and transportation; and ease and cost of siting, construction, operation, and closure. The relative significance of any technical guideline to its corresponding system guideline is site specific. Therefore, for each technical guideline, an evaluation of compliance with the qualifying condition shall be made in the context of the collection of system elements and the evidence related to that guideline, considering on balance the favorable conditions and the potentially adverse conditions identified at a site. Similarly, for each system guideline, such evaluation shall be made in the context of the group of technical guidelines and the evidence related to that system guideline. For purposes of recommending sites for development as respositories, such evidence shall include analyses of expected respository performance to assess the likelihood of demonstrating compliance with 40 CFR Part 191 and 10 CFR Part 60, in accordance with § 960.4-1. A site shall be disqualified at any time during the siting process if the evidence supports a finding by the DOE that a disqualifying condition exists or the qualifying condition of any system or technical guideline cannot be met. Comparisons between and among sites shall be based on the system guidelines, to the extent practicable and in accordance with the levels of relative significance specified above for the postclosure and the preclosure guidelines. Such comparisons are intended to allow comparative evaluations of sites in terms of the capabilities of the natural barriers for waste isolation and to identify innate deficiencies that could jeopardize compliance with such requirements. If the evidence for the sites is not adequate to substantiate such comparisons, then the comparisons shall be based on the groups of technical guidelines under the postclosure and the preclosure guidelines, considering the levels of relative significance appropriate to the postclosure and the preclosure guidelines and the order of importance appropriate to the subordinate groups within the preclosure guidelines. Comparative site evalua-

tions shall place primary importance on the natural barriers of the site. In such evaluations for the postclosure guidelines of Subpart C, engineered barriers shall be considered only to the extent necessary to obtain realistic source terms for comparative site evaluations based on the sensitivity of the natural barriers to such realistic engineered barriers. For a better understanding of the potential effects of engineered barriers on the overall performance of the repository system, these comparative evaluations shall consider a range of levels in the performance of the engineered barriers. That range of performance levels shall vary by at least a factor of 10 above and below the engineered-barrier performance requirements set forth in 10 CFR 60.113, and the range considered shall be identical for all sites compared. The comparisons shall assume equivalent engineered-barrier performance for all sites compared and shall be structured so that engineered barriers are not relied upon to compensate for deficiencies in the geologic media. Furthermore, engineered barriers shall not be used to compensate for an inadequate site; mask the innate deficiencies of a site; disguise the strengths and weaknesses of a site and the overall system; and mask differences between sites when they are compared. Site comparisons performed to support the recommendation of sites for the development of repositories in § 960.3-2-4 shall evaluate predicted releases of radionuclides to the accessible environment. For the purposes of such comparison, the accessible environment shall consist of the atmosphere, the land surface, any nearby surface water, and those portions of the lithosphere that are situated more than 10 kilometers in a horizontal direction from the outer boundary of the original location of the waste emplacement in the geologic repository. Releases of different radionuclides shall be combined by the methods specified in Appendix A of 40 CFR Part 191. The comparisons specified above shall consist of two comparative evaluations that predict radionuclide releases for 100,000 years after repository closure and shall be conducted as follows. First, the sites shall be compared by means of evaluations that emphasize the performance of the natural barriers at the site. Second, the sites shall be compared by means of evaluations that emphasize the performance of the total repository system. These second evaluations shall consider the expected performance of the repository system; be based on the expected performance of waste packages and waste forms, in compliance with the requirements of 10 CFR 60.113, and on the expected hydrologic and geochemical conditions at each site; and take credit for the expected performance of all other engineered components of the repository system. The comparison of isolation capability shall be one of the significant considerations in the recommendation of sites for the development of repositories. The first of the two comparative evaluations specified in the preceding paragraph shall take precedence unless the second comparative evaluation would lead to substantially different recommendations. In the latter case, the two comparative evaluations shall receive comparable consideration. Sites with predicted isolation capabilities that differ by less than a factor of 10, with similar uncertainties, may be assumed to provide equivalent isolation.

§ 960.3–2 Siting process.

The siting process begins with site screening for the identification of potentially acceptable sites. This process was completed for purposes of the first repository before the enactment of the Act, and the identification of such sites was made after enactment in accordance with the provisions of section 116(a) of the Act. The screening process for the identification of potentially acceptable sites for the second and subsequent repositories shall be conducted in accordance with the requirements specified in § 960.3-2-1 of this Subpart. The nomination of any site as suitable for characterization shall follow the process specified in § 960.3-2-2, and such nomination shall be accompanied by an environmental assessment as specified in section 112(b)(1)(E) of the Act. The recommendation of sites as candidate

sites for characterization and the recommendation of a characterized site for the development of a repository shall be accomplished in accordance with the requirements specified in §§960.3-2-3 and 960.3-2-4, respectively.

§ 960.3-2-1 Site screening for potentially acceptable sites.

To identify potentially acceptable sites for the development of other than the first repository, the process shall begin with site-screening activities that consider large land masses that contain rock formations of suitable depth, thickness, and lateral extent and have structural, hydrologic, and tectonic features favorable for waste containment and isolation. Within those large land masses, subsequent site-screening activities shall focus on successively smaller and increasingly more suitable land units. This process shall be developed in consultation with the States that contain land units under consideration. It shall be implemented in a sequence of steps that first applies the applicable disqualifying conditions to eliminate land units on the basis of the evidence specified in § 960.3-1-4-1 and in accordance with the application requirements set forth in Appendix III of this Part. After the disqualifying conditions have been applied, the favorable and potentially adverse conditions, as identified for each remaining land unit, shall be evaluated. The presence of favorable conditions shall favor a given land unit, while the presence of potentially adverse conditions shall penalize that land unit. Recognizing that favorable conditions and potentially adverse conditions for different technical guidelines can exist in the same land unit, the DOE shall seek to evaluate the composite favorability of each land unit. Land units that, in the aggregrate, exhibit potentially adverse conditions shall be deferred in favor of land units that exhibit favorable conditions. The siting provisions that require diversity of geohydrologic settings and rock types and consideration of regionality, as specified in §§ 960.3-1-1, 960.3-1-2, and 960.3-1-3, respectively, may be used to discriminate between land units and to establish the range of options in site screening. To identify a site as potentially accepta ble, the evidence shall support a find ing that the site is not disqualified i accordance with the application re quirements set forth in Appendix II of this Part and shall support the deci sion by the DOE to proceed the con tinued investigation of the site on th basis of the favorable and potentiall adverse conditions identified to date In continuation of the screening proc ess after such identification an before site nomination, the DOE ma defer from further consideration lan units or potentially acceptable sites o portions thereof on the basis of addi tional information or by the applica tion of the siting provisions for diversi ty of geohydrologic settings, diversit of rock types, and regionalit (§§ 960.3-1-1, 960.3-1-2, and 960.3-1-3 respectively). The deferral of poten tially acceptable sites will be describe in the environmental assessments tha accompany the nomination of at leas five sites as suitable for characteriza tion. In order to identify potentiall acceptable sites for the second an subsequent repositories, the Secretar shall *first* identify the State withi which the site is located in a decision basis document that describes th process and the considerations tha led to the identification of such sit and that has been issued previously i draft for review and comment by suc State. *Second*, when such document i final, the Secretary shall notify th Governor and the legislature of tha State and the tribal council of any af fected Indian tribe of the potentiall acceptable site.

§ 960.3-2-2 Nomination of sites as suitabl for characterization.

From the sites identified as poten tially acceptable, the Secretary shal nominate at least five sites determine suitable for site characterization fo the selection of each repository site For the second repository, at leas three of the sites shall not have been nominated previously. Any site nominated as suitable for characterizatio for the first repository, but not recommended as a candidate site for charac terization, may not be nominated a suitable for characterization for th

second repository. The nomination of a site as suitable for characterization shall be accompanied by an environmental assessment as specified in section 112(b)(1)(E) of the Act. Such nomination shall be based on evaluations in accordance with the guidelines of this Part, and the bases and relevant details of those evaluations and of the decision processes involved therein shall be contained in the environmental assessment for the site in the manner specified in this Subpart. The evidence required to support such evaluations and siting decisions is specified in § 960.3-1-4-2.

§ 960.3-2-2-1 Evaluation of all potentially acceptable sites.

First, in considering sites for nomination, each of the potentially acceptable sites shall be evaluated on the basis of the disqualifying conditions specified in the technical guidelines of Subparts C and D, in accordance with the application requirements set forth in Appendix III of this part. This evaluation shall support a finding by the DOE that such sites is not disqualified.

§ 960.3-2-2-2 Selection of sites within geohydrologic settings.

Second, the siting provision requiring diversity of geohydrologic settings, as specified in § 960.3-1-1, shall be applied to group all potentially acceptable sites according to their geohydrologic settings. *Third*, for those geohydrologic settings that contain more than one potentially acceptable site, the preferred site shall be selected on the basis of a comparative evaluation of all potentially acceptable sites in that setting. This evaluation shall consider the distinguishing characteristics displayed by the potentially acceptable sites within the setting and the related guidelines from Subparts C and D. That is, the appropriate guidelines shall be selected primarily on the basis of the kinds of evidence among sites for which distinguishing characteristics can be identified. Such comparative evaluation shall be made on the basis of the qualifying conditions for those guidelines, considering, on balance, the favorable conditions and potentially adverse conditions identified at each site. Due consideration shall also be given to the siting provisions specifying the basis for site evaluations in § 960.3-1-5, to the extent practicable, and diversity of rock types in § 960.3-1-2, if the circumstances so apply. If less than five geohydrologic settings are available for consideration, the above process shall be used to select two or more preferred sites from those settings that contain more than one potentially acceptable site, as required to obtain the number of sites to be nominated as suitable for characterization. For purposes of the second and subsequent repositories, due consideration shall also be given to the siting provision for regionality as specified in § 960.3-1-3. *Fourth*, each preferred site within a geohydrologic setting shall be evaluated as to whether such site is suitable for the development of a repository under the qualifying condition of each guideline specified in Subparts C and D that does not require site characterization as a prerequisite for the application of such guideline. The guidelines considered appropriate to this evaluation have been selected on the basis of their exclusion under the definition of site characterization as specified in § 960.2. Although the final application of these guidelines, in accordance with the provisions set forth in Appendix III of this part, does not require geologic data from site-characterization activities, such application will require additional data beyond those specified in Appendix IV of this part, which will be obtained concurrently with site characterization. Such guidelines include those specified in § 960.4-2-8-2 (Site Ownership and Control) of Subpart C; §§ 960.5-1(a)(1) and 960.5-1(a)(2) of Subpart D (preclosure system guidelines for radiological safety and environmental quality, socioeconomics, and transportation); and §§ 960.5-2-1 through 960.5-2-7 of Subpart D (Population Density and Distribution, Site Ownership and Control, Meteorology, Offsite Installations and Operations, Environmental Quality, Socioeconomic Impacts, and Transportation). This evaluation shall consider on balance those favorable conditions and potentially adverse conditions identified as such at a preferred site in

relation to the qualifying condition of each such guideline. For each such guideline, this evaluation shall focus on the suitability of the site for the development of a repository by considering the activities from the start of site characterization through decommissioning and shall support a finding by the DOE in accordance with the application requirements set forth in Appendix III of this part. *Fifth*, each preferred site within a geohydrologic setting shall be evaluated as to whether such site is suitable for site characterization under the qualifying conditions of those guidelines specified in Subparts C and D that require characterization (i.e., subsurface geologic, hydrologic, and geochemical data gathering). Such guidelines include those specified in § 960.4-1(a) (postclosure system guideline); §§ 960.4-2-1 through 960.4-2-8-1 of Subpart C (Geohydrology, Geochemistry, Rock Characteristics, Climatic Changes, Erosion, Dissolution, Tectonics, Human Interference, and Natural Resources); §960.5-1(a)(3) (preclosure system guideline for ease and cost of siting, construction, operation, and closure); and § 960.5-2-8 through 960.5-2-11 of Subpart D (Surface Characteristics, Rock Characteristics, Hydrology, and Tectonics). This evaluation shall consider on balance the favorable conditions and potentially adverse conditions identified as such at a preferred site in relation to the qualifying condition of each such guideline. For each such guideline, this evaluation shall focus on the suitability of the site for characterization and shall support a finding by the DOE in accordance with the application requirements set forth in Appendix III of this part.

§ 960.3-2-2-3 Comparative evaluation of all sites proposed for nomination.

Sixth, for those potentially acceptable sites to be proposed for nomination, as determined by the process specified in § 960.3-2-2-2, a reasonable comparative evaluation of each such site with all other such sites shall be made. For each site and for each guideline specified in Subparts C and D, the DOE shall summarize the evaluations and findings specified under § 960.3-2-2-1 and under the fourth and fifth provisions of § 960.3-2-2-2. Each such summary shall allow comparisons to be made among sites on this basis of each guideline.

§ 960.3-2-2-4 The environmental assessment.

To document the process specified above, and in compliance with section 112(b)(1)(E) of the Act, an environmental assessment shall be prepared for each site proposed for nomination as suitable for characterization. Each such environmental assessment shall describe the decision process by which such site was proposed for nomination as described in the preceding six steps and shall contain or reference the evidence that supports such process according to the requirements of § 960.3-1-4-2 and Appendix IV of this part. As specified in the Act, each environmental assessment shall include an evaluation of the effects of the site-characterization activities at the site on public health and safety and the environment; a discussion of alternative activities related to site characterization that may be taken to avoid such impact; and an assessment of the regional and local impacts of locating a repository at the site. The draft environmental assessment for each site proposed for nomination as suitable for characterization shall be made available by the DOE for public comment after the Secretary has notified the Governor and legislature of the State in which the site is located, and the governing body of the affected Indian tribe where such site is located, of such impending availability.

§ 960.3-2-2-5 Formal site nomination.

After the final environmental assessments have been prepared, the Secretary shall nominate at least five sites that he determines suitable for site characterization for the selection of a repository site, and, in so doing, he shall cause to have published in the FEDERAL REGISTER a notice specifying the sites so nominated and announcing the availability of the final environmental assessments for such sites. This determination by the Secretary shall be based on the final environ-

mental assessments for such sites, including, in particular, consideration of the available evidence, evaluations, and the resultant findings for the guidelines of Subparts C and D so specified under the fourth and fifth provisions of § 960.3-2-2-2. Before nominating a site, the Secretary shall notify the Governor and legislature of the State in which the site is located, and the governing body of the affected Indian tribe where such site is located, of such nomination and the basis for such nomination.

§ 960.3-2-3 Recommendation of sites for characterization.

After the nomination of at least five sites as suitable for site characterization for the selection of the first repository, the Secretary shall recommend in writing to the President not less than three candidate sites for such characterization. The recommendation decision shall be based on the available geophysical, geologic, geochemical, and hydrologic data; other information; associated evaluations and findings reported in the environmental assessments accompanying the nominations; and the considerations specified below, unless the Secretary certifies that such available data will not be adequate to satisfy applicable requirements of the Act in the absence of further preliminary borings or excavations. On the basis of the evidence and in accordance with the siting provision specifying the basis for site evaluations in § 960.3-1-5, the sites nominated as suitable for characterization shall be considered as to their order of preference as candidate sites for characterization. Subsequently, the siting provisions specifying diversity of geohydrologic settings, diversity of rock types, and, after the first repository, consideration of regionality in §§ 960.3-1-1, 960.3-1-2, and 960.3-1-3, respectively, shall be considered to determine a final order of preference for the characterization of such sites. Considering this order of preference together with the available siting alternatives specified in the Act, the sites recommended as candidate sites for characterization shall offer, on balance, the most advantageous combination of characteristics and conditions for the successful development of repositories at such sites. The process for the recommendation of sites as candidate sites for characterization for the selection of any subsequent repository shall be the same as that specified above for the first repository.

§ 960.3-2-4 Recommendation of sites for the development of repositories.

After completion of site characterization and nongeologic data gathering activities at the candidate sites for the development of the first repository, or from all of the characterized sites for the development of subsequent repositories, the candidate sites shall be compared with each other on the basis of the guidelines specified in Subparts C and D according to the siting provision specifying the basis for site evaluations in § 960.3-1-5. This comparison shall lead to a recommendation by the Secretary to the President of a site for the development of a repository. Together with any recommendation to the President to approve a site for the development of a repository, the Secretary shall make available to the public, and submit to the President, a comprehensive statement of the basis of such recommendation pursuant to the requirements specified in section 114(a)(1) of the Act, including an environmental impact statement prepared in accordance with the provisions of sections 114(a)(1)(D) and 114(f) of the Act. The environmental impact statement shall include the results of the comparative evaluation specified above and a description of the decision process that resulted in the selection of the candidate site recommended for the development of such repository.

§ 960.3-3 Consultation.

The DOE shall provide to designated officials of the affected States and to the governing bodies of any affected Indian tribe timely and complete information regarding determinations or plans made with respect to the siting, site characterization, design, development, construction, operation, closure, decommissioning, licensing, or regulation of a repository. Written responses to written requests for information from the designated officials of affect-

ed States or affected Indian tribes will be provided within 30 days after receipt of the written requests. In performing any study of an area for the purpose of determining the suitability of such area for the development of a repository, the DOE shall consult and cooperate with the Governor and the legislature of an affected State and the governing body of an affected Indian tribe in an effort to resolve concerns regarding public health and safety, environmental impacts, socioeconomic impacts, and technical aspects of the siting process. After notifying affected States and affected Indian tribes that potentially acceptable sites have been identified, or that a site has been approved for characterization, the DOE shall seek to enter into binding written agreements with such affected States or affected Indian tribes in accordance with the requirements of the Act. The DOE shall also consult, as appropriate, with other Federal agencies.

§ 960.3-4 Environmental impacts.

Environmental impacts shall be considered by the DOE throughout the site characterization, site selection, and repository development process. The DOE shall mitigate significant adverse environmental impacts, to the extent practicable, during site characterization and repository construction, operation, closure, and decommissioning.

Subpart C—Postclosure Guidelines

§ 960.4 Postclosure guidelines.

The guidelines in this subpart specify the factors to be considered in evaluating and comparing sites on the basis of expected repository performance after closure. The postclosure guidelines are separated into a system guideline and eight technical guidelines. The system guideline establishes waste containment and isolation requirements that are based on NRC and EPA regulations. These requirements must be met by the repository system, which contains natural barriers and engineered barriers. The engineered barriers will be designed to complement the natural barriers, which provide the primary means for waste isolation.

§ 960.4-1 System guideline.

(a) *Qualifying Condition.* The geologic setting at the site shall allow for the physical separation of radioactive waste from the accessible environment after closure in accordance with the requirements of 40 CFR Part 191, Subpart B, as implemented by the provisions of 10 CFR Part 60. The geologic setting at the site will allow for the use of engineered barriers to ensure compliance with the requirements of 40 CFR Part 191 and 10 CFR Part 60 (see Appendix I of this part).

§ 960.4-2 Technical guidelines.

The technical guidelines in this subpart set forth qualifying, favorable, potentially adverse, and, in five guidelines, disqualifying conditions on the characteristics, processes, and events that may influence the performance of a repository system after closure. The favorable conditions and the potentially adverse conditions under each guideline are *not* listed in any assumed order of importance. Potentially adverse conditions will be considered if they affect waste isolation within the controlled area even though such conditions may occur outside the controlled area. The technical guidelines that follow establish conditions that shall be considered in determining compliance with the qualifying condition of the postclosure system guideline. For each technical guideline, an evaluation of qualification or disqualification shall be made in accordance with the requirements specified in Subpart B.

§ 960.4-2-1 Geohydrology.

(a) *Qualifying Condition.* The present and expected geohydrologic setting of a site shall be compatible with waste containment and isolation. The geohydrologic setting, considering the characteristics of and the processes operating within the geologic setting, shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements specified in 10 CFR 60.113 for

radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) Site conditions such that the pre-waste-emplacement ground-water travel time along any path of likely radionuclide travel from the disturbed zone to the accessible environment would be more than 10,000 years.

(2) The nature and rates of hydrologic processes operating within the geologic setting during the Quaternary Period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years.

(3) Sites that have stratigraphic, structural, and hydrologic features such that the geohydrologic system can be readily characterized and modeled with reasonable certainty.

(4) For disposal in the saturated zone, at least one of the following pre-waste-emplacement conditions exists:

(i) A host rock and immediately surrounding geohydrologic units with low hydraulic conductivities.

(ii) A downward or predominantly horizontal hydraulic gradient in the host rock and in the immediately surrounding geohydrologic units.

(iii) A low hydraulic gradient in and between the host rock and the immediately surrounding geohydrologic units.

(iv) High effective porosity together with low hydraulic conductivity in rock units along paths of likely radionuclide travel between the host rock and the accessible environment.

(5) For disposal in the unsaturated zone, at least one of the following pre-waste-emplacement conditions exists:

(i) A low and nearly constant degree of saturation in the host rock and in the immediately surrounding geohydrologic units.

(ii) A water table sufficiently below the underground facility such that the fully saturated voids continuous with the water table do not encounter the host rock.

(iii) A geohydrologic unit above the host rock that would divert the downward infiltration of water beyond the limits of the emplaced waste.

(iv) A host rock that provides for free drainage.

(v) A climatic regime in which the average annual historical precipitation is a small fraction of the average annual potential evapotranspiration.

NOTE: The DOE will, in accordance with the general principles set forth in § 960.1 of these regulations, revise the guidelines as necessary, to ensure consistency with the final NRC regulations on the unsaturated zone, which were published as a proposed rule on February 16, 1984, in 49 FR 5934.

(c) *Potentially Adverse Conditions.* (1) Expected changes in geohydrologic conditions—such as changes in the hydraulic gradient, the hydraulic conductivity, the effective porosity, and the ground-water flux through the host rock and the surrounding geohydrologic units—sufficient to significantly increase the transport of radionuclides to the accessible environment as compared with pre-waste-emplacement conditions.

(2) The presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment.

(3) The presence in the geologic setting of stratigraphic or structural features—such as dikes, sills, faults, shear zones, folds, dissolution effects, or brine pockets—if their presence could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system.

(d) *Disqualifying Condition.* A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

§ 960.4-2-2 Geochemistry.

(a) *Qualifying Condition.* The present and expected geochemical characteristics of a site shall be compatible with waste containment and isolation. Considering the likely chemical interactions among radionuclides, the host rock, and the ground water, the characteristics of and the processes operating within the geologic set-

ting shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements specified in 10 CFR 60.113 for radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) The nature and rates of the geochemical processes operating within the geologic setting during the Quaternary Period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years.

(2) Geochemical conditions that promote the precipitation, diffusion into the rock matrix, or sorption of radionuclides; inhibit the formation of particulates, colloids, inorganic complexes, or organic complexes that increase the mobility of radionuclides; or inhibit the transport of radionuclides by particulates, colloids, or complexes.

(3) Mineral assemblages that, when subjected to expected repository conditions, would remain unaltered or would alter to mineral assemblages with equal or increased capability to retard radionuclide transport.

(4) A combination of expected geochemical conditions and a volumetric flow rate of water in the host rock that would allow less than 0.001 percent per year of the total radionuclide inventory in the repository at 1,000 years to be dissolved.

(5) Any combination of geochemical and physical retardation processes that would decrease the predicted peak cumulative releases of radionuclides to the accessible environment by a factor of 10 as compared to those predicted on the basis of ground-water travel time without such retardation.

(c) *Potentially Adverse Conditions.* (1) Ground-water conditions in the host rock that could affect the solubility or the chemical reactivity of the engineered-barrier system to the extent that the expected repository performance could be compromised.

(2) Geochemical processes or conditions that could reduce the sorption of radionuclides or degrade the rock strength.

(3) Pre-waste-emplacement groundwater conditions in the host rock that are chemically oxidizing.

§ 960.4-2-3 Rock characteristics.

(a) *Qualifying condition.* The present and expected characteristics of the host rock and surrounding units shall be capable of accommodating the thermal, chemical, mechanical, and radiation stresses expected to be induced by repository construction, operation, and closure and by expected interactions among the waste, host rock, ground water, and engineered components. The characteristics of and the processes operating within the geologic setting shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements set forth in 10 CFR 60.113 for radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) A host rock that is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

(2) A host rock with a high thermal conductivity, a low coefficient of thermal expansion, or sufficient ductility to seal fractures induced by repository construction, operation, or closure or by interactions among the waste, host rock, ground water, and engineered components.

(c) *Potentially Adverse Conditions.* (1) Rock conditions that could require engineering measures beyond reasonably available technology for the construction, operation, and closure of the repository, if such measures are necessary to ensure waste containment or isolation.

(2) Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

(3) A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the

host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

§ 960.4-2-4 Climatic changes.

(a) *Qualifying Condition.* The site shall be located where future climatic conditions will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likely future climatic conditions at a site, the DOE will consider the global, regional, and site climatic patterns during the Quaternary Period, considering the geomorphic evidence of the climatic conditions in the geologic setting.

(b) *Favorable Conditions.* (1) A surface-water system such that expected climatic cycles over the next 100,000 years would not adversely affect waste isolation.

(2) A geologic setting in which climatic changes have had little effect on the hydrologic system throughout the Quaternary Period.

(c) *Potentially Adverse Conditions.* (1) Evidence that the water table could rise sufficiently over the next 10,000 years to saturate the underground facility in a previously unsaturated host rock.

(2) Evidence that climatic changes over the next 10,000 years could cause perturbations in the hydraulic gradient, the hydraulic conductivity, the effective porosity, or the ground-water flux through the host rock and the surrounding geohydrologic units, sufficient to significantly increase the transport of radionuclides to the accessible environment.

§ 960.4-2-5 Erosion.

(a) *Qualifying Condition.* The site shall allow the underground facility to be placed at a depth such that erosional processes acting upon the surface will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of potentially disruptive erosional processes, the DOE will consider the climatic, tectonic, and geomorphic evidence of rates and patterns of erosion in the geologic setting during the Quaternary Period.

(b) *Favorable Conditions.* (1) Site conditions that permit the emplacement of waste at a depth of at least 300 meters below the directly overlying ground surface.

(2) A geologic setting where the nature and rates of the erosional processes that have been operating during the Quaternary Period are predicted to have less than one chance in 10,000 over the next 10,000 years of leading to releases of radionuclides to the accessible environment.

(3) Site conditions such that waste exhumation would not be expected to occur during the first one million years after repository closure.

(c) *Potentially Adverse Conditions.* (1) A geologic setting that shows evidence of extreme erosion during the Quaternary Period.

(2) A geologic setting where the nature and rates of geomorphic processes that have been operating during the Quaternary Period could, during the first 10,000 years after closure, adversely affect the ability of the geologic repository to isolate the waste.

(d) *Disqualifying Condition.* The site shall be *disqualified* if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.

§ 960.4-2-6 Dissolution.

(a) *Qualifying Condition.* The site shall be located such that any subsurface rock dissolution will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of dissolution within the geologic setting at a site, the DOE will consider the evidence of dissolution within that setting during the Quaternary Period, including the locations and characteristics of dissolution fronts or other dissolution features, if identified.

(b) *Favorable Condition.* No evidence that the host rock within the site was subject to significant dissolution during the Quaternary Period.

(c) *Potentially Adverse Condition.* Evidence of dissolution within the geologic setting—such as breccia pipes, dissolution cavities, significant volumetric reduction of the host rock or surrounding strata, or any structural collapse—such that a hydraulic interconnection leading to a loss of waste isolation could occur.

(d) *Disqualifying Condition.* The site shall be *disqualified* if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.

§ 960.4-2-7 Tectonics.

(a) *Qualifying Condition.* The site shall be located in a geologic setting where future tectonic processes or events will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of potentially disruptive tectonic processes or events, the DOE will consider the structural, stratigraphic, geophysical, and seismic evidence for the nature and rates of tectonic processes and events in the geologic setting during the Quaternary Period.

(b) *Favorable Condition.* The nature and rates of igneous activity and tectonic processes (such as uplift, subsidence, faulting, or folding), if any, operating within the geologic setting during the Quaternary Period would, if continued into the future, have less than one chance in 10,000 over the first 10,000 years after closure of leading to releases of radionuclides to the accessible environment.

(c) *Potentially Adverse Conditions.* (1) Evidence of active folding, faulting, diapirism, uplift, subsidence, or other tectonic processes or igneous activity within the geologic setting during the Quaternary Period.

(2) Historical earthquakes within the geologic setting of such magnitude and intensity that, if they recurred, could affect waste containment or isolation.

(3) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or the magnitude of earthquakes within the geologic setting may increase.

(4) More-frequent occurrences o earthquakes or earthquakes of highe magnitude than are representative o the region in which the geologic setting is located.

(5) Potential for natural phenomen such as landslides, subsidence, or vol canic activity of such magnitudes tha they could create large-scale surface water impoundments that coul change the regional ground-water flow system.

(6) Potential for tectonic deforma tions—such as uplift, subsidence, fold ing, or faulting—that could adversely affect the regional ground-water flow system.

(d) *Disqualifying Condition.* A sit shall be disqualified if, based on th geologic record during the Quaternar Period, the nature and rates of faul movement or other ground motion ar expected to be such that a loss o waste isolation is likely to occur.

§ 960.4-2-8 Human interference.

The site shall be located such tha activities by future generations at o near the site will not be likely to affec waste containment and isolation. I assessing the likelihood of such activities, the DOE will consider the estimated effectiveness of the permanen markers and records required by 1 CFR Part 60, taking into account site specific factors, as stated in §§ 960.4-2 8-1 and 960.4-2-8-2, that could com promise their continued effectiveness.

§ 960.4-2-8-1 Natural resources.

(a) *Qualifying Condition.* This sit shall be located such that—consider ing permanent markers and record and reasonable projections of value scarcity, and technology—the natura resources, including ground water suit able for crop irrigation or human con sumption without treatment, presen at or near the site will not be likely t give rise to interference activities tha would lead to radionuclide release greater than those allowable unde the requirements specified in § 960.4-

(b) *Favorable Conditions.* (1) N known natural resources that have c are projected to have in the foresee

ble future a value great enough to be considered a commercially extractable resource.

(2) Ground water with 10,000 parts per million or more of total dissolved solids along any path of likely radionuclide travel from the host rock to the accessible environment.

(c) *Potentially Adverse Conditions.* (1) Indications that the site contains naturally occurring materials, whether or not actually identified in such form that (i) economic extraction is potentially feasible during the foreseeable future or (ii) such materials have a greater gross value, net value, or commercial potential than the average for other areas of similar size that are representative of, and located in, the geologic setting.

(2) Evidence of subsurface mining or extraction for resources within the site if it could affect waste containment or isolation.

(3) Evidence of drilling within the site for any purpose other than repository-site evaluation to a depth sufficient to affect waste containment and isolation.

(4) Evidence of a significant concentration of any naturally occurring material that is not widely available from other sources.

(5) Potential for foreseeable human activities—such as ground-water withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments—that could adversely change portions of the ground-water flow system important to waste isolation.

(d) *Disqualifying Conditions.* A site shall be disqualified if—

(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or

(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

§ 960.4-2-8-2 Site ownership and control.

(a) *Qualifying Condition.* The site shall be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR Part 60, ownership, surface and subsurface rights, and control of access that are required in order that potential surface and subsurface activities as the site will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1.

(b) *Favorable Condition.* Present ownership and control of land and all surface and subsurface rights by the DOE.

(c) *Potentially Adverse Condition.* Projected land-ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings.

Subpart D—Preclosure Guidelines

§ 960.5 Preclosure guidelines.

The guidelines in this subpart specify the factors to be considered in evaluating and comparing sites on the basis of expected repository performance before closure. The preclosure guidelines are separated into three system guidelines and eleven technical guidelines.

§ 960.5-1 System guidelines.

(a) *Qualifying Conditions*—(1) *Preclosure Radiological Safety.* Any projected radiological exposures of the general public and any projected releases of radioactive materials to restricted and unrestricted areas during repository operation and closure shall meet the applicable safety requirements set forth in 10 CFR Part 20, 10 CFR Part 60, and 40 CFR 191, Subpart A (see Appendix II of this part).

(2) *Environment, Socioeconomics, and Transportation.* During repository siting, construction, operation, closure, and decommissioning the public and the environment shall be adequately protected from the hazards posed by the disposal of radioactive waste.

(3) *Ease and Cost of Siting, Construction, Operation, and Closure.* Repository siting, construction, operation, and closure shall be demonstrated to be technically feasible on the basis of reasonably available technology, and the associated costs shall be demonstrated to be reasonable relative to other available and comparable siting options.

§ 960.5-2 Technical guidelines.

The technical guidelines in this subpart set forth qualifying, favorable, potentially adverse, and, in seven guidelines, disqualifying conditions for the characteristics, processes, and events that influence the suitability of a site relative to the preclosure system guidelines. These conditions are separated into three main groups: Preclosure radiological safety; environment, socioeconomics, and transportation; and ease and cost of siting, construction, operation, and closure. The first group includes conditions on population density and distribution, site ownership and control, meteorology, and offsite installations and operations. The second group includes conditions related to environmental quality and socioeconomic impacts in areas potentially affected by a repository and to the transportation of waste to a repository site. The third group includes conditions on the surface characteristics of the site, the characteristics of the host rock and surrounding strata, hydrology, and tectonics. The individual technical guidelines within each group, as well as the favorable conditions and the potentially adverse conditions under each guideline, are not listed in any assumed order of importance. The technical guidelines that follow establish conditions that shall be considered in determining compliance with the qualifying conditions of the preclosure system guidelines. For each technical guideline, an evaluation of qualification or disqualification shall be made in accordance with the requirements specified in Subpart B.

PRECLOSURE RADIOLOGICAL SAFETY

§ 960.5-2-1 Population Density and Distribution.

(a) *Qualifying Condition.* The site shall be located such that, during repository operation and closure, (1) the expected average radiation dose to members of the public within any highly populated area will not be likely to exceed a small fraction of the limits allowable under the requirements specified in § 960.5-1(a)(1), and (2) the expected radiation dose to any member of the public in an unrestricted area will not be likely to exceed the limit allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Conditions.* (1) A low population density in the general region of the site.

(2) Remoteness of site from highly populated areas.

(c) *Potentially Adverse Conditions* (1) High residential, seasonal, or daytime population density within the projected site boundaries.

(2) Proximity of the site to highly populated areas, or to areas having at least 1,000 individuals in an area 1 mile by 1 mile as defined by the most recent decennial count of the U.S census.

(d) *Disqualifying Conditions.* A site shall be *disqualified* if—

(1) Any surface facility of a repository would be located in a highly populated area; or

(2) Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S census; or

(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or when issued by the NRC, in 10 CFR Part 60, Subpart I, "Emergency Planning Criteria."

§ 960.5-2-2 Site Ownership and Control.

(a) *Qualifying Condition.* The site shall be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR 60.121, ownership, surface and subsurface rights, and control of access that are required in order that surface and subsurface activities during repository operation and closure will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Present ownership and control of land and all surface and subsurface mineral and water rights by the DOE.

(c) *Potentially Adverse Condition.* Projected land-ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings.

§ 960.5-2-3 Meteorology.

(a) *Qualifying Condition.* The site shall be located such that expected meteorological conditions during repository operation and closure will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Prevailing meteorological conditions such that any radioactive releases to the atmosphere during repository operation and closure would be effectively dispersed, thereby reducing significantly the likelihood of unacceptable exposure to any member of the public in the vicinity of the repository.

(c) *Potentially Adverse Conditions.* (1) Prevailing meteorological conditions such that radioactive emissions from repository operation of closure could be preferentially transported toward localities in the vicinity of the repository with higher population densities than are the average for the region.

(2) History of extreme weather phenomena—such as hurricanes, tornadoes, severe floods, or severe and frequent winter storms—that could significantly affect repository operation or closure.

§ 960.5-2-4 Offsite installations and operations.

(a) *Qualifying Condition.* The site shall be located such that present projected effects from nearby industrial, transportation, and military installations and operations, including atomic energy defense activities, (1) will not significantly affect repository siting, construction, operation, closure, or decommissioning or can be accommodated by engineering measures and (2), when considered together with emissions from repository operation and closure, will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Absence of contributing radioactive releases from other nuclear installations and operations that must be considered under the requirements of 40 CFR 191, Subpart A.

(c) *Potentially Adverse Conditions.* (1) The presence of nearby potentially hazardous installations or operations that could adversely affect repository operation or closure.

(2) Presence of other nuclear installations and operations, subject to the requirements of 40 CFR Part 190 or 40 CFR 191, Subpart A, with actual or projected releases near the maximum value permissible under those standards.

(d) *Disqualifying Condition.* A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning.

ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

§ 960.5-2-5 Environmental quality.

(a) *Qualifying Condition.* The site shall be located such that (1) the quality of the environment in the affected area during this and future generations will be adequately protected during repository siting, construction, operation, closure, and decommissioning, and projected environmental impacts in the affected area can be miti-

gated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors; and (2) the requirements specified in § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Projected ability to meet, within time constraints, all Federal, State, and local procedural and substantive environmental requirements applicable to the site and the activities proposed to take place thereon.

(2) Potential significant adverse environmental impacts to present and future generations can be mitigated to an insignificant level through the application of reasonable measures, taking into account programmatic, technical, social, economic, and environmental factors.

(c) *Potentially Adverse Conditions.* (1) Projected major conflict with applicable Federal, State, or local environmental requirements.

(2) Projected significant adverse environmental impacts that cannot be avoided or mitigated.

(3) Proximity to, or projected significant adverse environmental impacts of the repository or its support facilities on, a component of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Land.

(4) Proximity to, and projected significant adverse environmental impacts of the repository or its support facilities on, a significant State or regional protected resource area, such as a State park, a wildlife area, or a historical area.

(5) Proximity to, and projected significant adverse environmental impacts of the repository and its support facilities on, a significant Native American resource, such as a major Indian religious site, or other sites of unique cultural interest.

(6) Presence of critical habitats for threatened or endangered species that may be compromised by the repository or its support facilities.

(d) *Disqualifying Conditions.* Any of the following conditions shall *disqualify* a site:

(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment in the affected area could not be adequately protected or projected environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.

(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.

(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act.

§ 960.5-2-6 Socioeconomic impacts.

(a) *Qualifying Condition.* The site shall be located such that (1) any significant adverse social and/or economic impacts induced in communities and surrounding regions by repository siting, construction, operation, closure, and decommissioning can be offset by reasonable mitigation or compensation, as determined by a process of analysis, planning, and consultation among the DOE, affected State and local government jurisdictions, and affected Indian tribes; and (2) the requirements specified in § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Ability of an affected area to absorb the project-related population changes without significant disruptions of community services and without significant impacts on housing supply and demand.

(2) Availability of an adequate labor force in the affected area.

(3) Projected net increases in employment and business sales, improved

community services, and increased government revenues in the affected area.

(4) No projected substantial disruption of primary sectors of the economy of the affected area.

(c) *Potentially Adverse Conditions.* (1) Potential for significant repository-related impacts on community services, housing supply and demand, and the finances of State and local government agencies in the affected area.

(2) Lack of an adequate labor force in the affected area.

(3) Need for repository-related purchase or acquisition of water rights, if such rights could have significant adverse impacts on the present or future development of the affected area.

(4) Potential for major disruptions of primary sectors of the economy of the affected area.

(d) *Disqualifying Condition.* A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures.

§ 960.5-2-7 Transportation.

(a) *Qualifying Condition.* The site shall be located such that (1) the access routes constructed from existing local highways and railroads to the site (i) will not conflict irreconcilably with the previously designated use of any resource listed in § 960.5-2-5(d) (2) and (3); (ii) can be designed and constructed using reasonably available technology; (iii) will not require transportation system components to meet performance standards more stringent than those specified in the applicable DOT and NRC regulations, nor require the development of new packaging containment technology; (iv) will allow transportation operations to be conducted without causing an unacceptable risk to the public or unacceptable environmental impacts, taking into account programmatic, technical, social, economic, and environmental factors; and (2) the requirements of § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Availability of access routes from local existing highways and railroads to the site which have any of the following characteristics:

(i) Such routes are relatively short and economical to construct as compared to access routes for other comparable siting options.

(ii) Federal condemnation is not required to acquire rights-of-way for the access routes.

(iii) Cuts, fills, tunnels, or bridges are not required.

(iv) Such routes are free of sharp curves or steep grades and are not likely to be affected by landslides or rock slides.

(v) Such routes bypass local cities and towns.

(2) Proximity to local highways and railroads that provide access to regional highways and railroads and are adequate to serve the repository without significant upgrading or reconstruction.

(3) Proximity to regional highways, mainline railroads, or inland waterways that provide access to the national transportation system.

(4) Availability of a regional railroad system with a minimum number of interchange points at which train crew and equipment changes would be required.

(5) Total projected life-cycle cost and risk for transportation of all wastes designated for the repository site which are significantly lower than those for comparable siting options, considering locations of present and potential sources of waste, interim storage facilities, and other repositories.

(6) Availability of regional and local carriers—truck, rail, and water—which have the capability and are willing to handle waste shipments to the repository.

(7) Absence of legal impediment with regard to compliance with Federal regulations for the transportation of waste in or through the affected State and adjoining States.

(8) Plans, procedures, and capabilities for response to radioactive waste transportation accidents in the affected State that are completed or being developed.

(9) A regional meteorological history indicating that significant transportation disruptions would not be routine seasonal occurrences.

(c) *Potentially Adverse Conditions.* (1) Access routes to existing local highways and railroads that are expensive to construct relative to comparable siting options.

(2) Terrain between the site and existing local highways and railroads such that steep grades, sharp switchbacks, rivers, lakes, landslides, rock slides, or potential sources of hazard to incoming waste shipments will be encountered along access routes to the site.

(3) Existing local highways and railroads that could require significant reconstruction or upgrading to provide adequate routes to the regional and national transportation system.

(4) Any local condition that could cause the transportation-related costs, environmental impacts, or risk to public health and safety from waste transportation operations to be significantly greater than those projected for other comparable siting options.

EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

§ 960.5-2-8 Surface characteristics.

(a) *Qualifying Condition.* The site shall be located such that, considering the surface characteristics and conditions of the site and surrounding area, including surface-water systems and the terrain, the requirements specified in § 960.5-1(a)(3) can be met during repository siting, construction, operation, and closure.

(b) *Favorable Conditions.* (1) Generally flat terrain.

(2) Generally well-drained terrain.

(c) *Potentially Adverse Condition.* Surface characteristics that could lead to the flooding of surface or underground facilities by the occupancy and modification of flood plains, the failure of existing or planned man-made surface-water impoundments, or the failure of engineered components of the repository.

§ 960.5-2-9 Rock characteristics.

(a) *Qualifying Condition.* The site shall be located such that (1) the thickness and lateral extent and the characteristics and composition of the host rock will be suitable for accommodation of the underground facility; (2) repository construction, operation, and closure will not cause undue hazard to personnel; and (3) the requirements specified in § 960.5-1(a)(3) can be met.

(b) *Favorable Conditions.* (1) A host rock that is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility.

(2) A host rock with characteristics that would require minimal or no artificial support for underground openings to ensure safe repository construction, operation, and closure.

(c) *Potentially Adverse Conditions.* (1) A host rock that is suitable for repository construction, operation, and closure, but is so thin or laterally restricted that little flexibility is available for selecting the depth, configuration, or location of an underground facility.

(2) In situ characteristics and conditions that could require engineering measures beyond reasonably available technology in the construction of the shafts and underground facility.

(3) Geomechanical properties that could necessitate extensive maintenance of the underground openings during repository operation and closure.

(4) Potential for such phenomena as thermally induced fracturing, the hydration and dehydration of mineral components, or other physical, chemical, or radiation-related phenomena that could lead to safety hazards or difficulty in retrieval during repository operation.

(5) Existing faults, shear zones, pressurized brine pockets, dissolution effects, or other stratigraphic or structural features that could compromise the safety of repository personnel because of water inflow or construction problems.

(d) *Disqualifying Condition.* The site shall be *disqualified* if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to

the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.

§ 960.5-2-10 Hydrology.

(a) *Qualifying Condition.* The site shall be located such that the geohydrologic setting of the site will (1) be compatible with the activities required for repository construction, operation, and closure; (2) not compromise the intended functions of the shaft liners and seals; and (3) permit the requirements specified in § 960.5-1(a)(3) to be met.

(b) *Favorable Conditions.* (1) Absence of aquifers between the host rock and the land surface.

(2) Absence of surface-water systems that could potentially cause flooding of the repository.

(3) Availability of the water required for repository construction, operation, and closure.

(c) *Potentially Adverse Condition.* Ground-water conditions that could require complex engineering measures that are beyond reasonably available technology for repository construction, operation, and closure.

(d) *Disqualifying Condition.* A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

§ 960.5-2-11 Tectonics.

(a) *Qualifying Conditions.* The site shall be located in a geologic setting in which any projected effects of expected tectonic phenomena or igneous activity on repository construction, operation, or closure will be such that the requirements specified in § 960.5-1(a)(3) can be met.

(b) *Favorable Condition.* The nature and rates of faulting, if any, within the geologic setting are such that the magnitude and intensity of the associated seismicity are significantly less than those generally allowable for the construction and operation of nuclear facilities.

(c) *Potentially Adverse Conditions.* (1) Evidence of active faulting within the geologic setting.

(2) Historical earthquakes or past man-induced seismicity that, if either were to recur, could produce ground motion at the site in excess of reasonable design limits.

(3) Evidence, based on correlations of earthquakes with tectonic processes and features, (e.g., faults) within the geologic setting, that the magnitude of earthquakes at the site during repository construction, operation, and closure may be larger then predicted from historical seismicity.

(d) *Disqualifying Condition.* A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

Appendix I—NRC and EPA Requirements for Postclosure Repository Performance

Under proposed 40 CFR Part 191, Subpart B—*Environmental Standards for Disposal*, § 191.13, "Containment Requirements", specifies that for 10,000 years after disposal (a) releases of radioactive materials to the accessible environment that are estimated to have more than one chance in 100 of occurring over a 10,000 year period ("reasonably foreseeable releases") shall be projected to be less than the quantities permitted by Table 2 of that regulation's Appendix; and (b) for "very unlikely releases" (i.e., those estimated to have between one chance in 100 and one chance in 10,000 of occurring over a 10,000 year period), the limits specified in Table 2 would be multiplied by 10. The basis for Table 2 is an upper limit on long term risks of 1,000 health effects over 10,000 years for a repository containing wastes generated from 100,000 metric tons of heavy metal of reactor fuel. For releases involving more than one radionuclide, the allowed release for each radionuclide is reduced to the fraction of its limit that insures that the overall limit on harm is not exceeded. Additionally, to provide confidence needed for compliance with the containment requirements specified above, § 191.14, "Assurance Requirements", specifies the disposal of radioactive waste in accordance with seven requirements, relating

to prompt disposal of waste; selection and design of disposal systems to keep releases to the accessible environment as small as reasonably achievable; engineered and natural barriers; nonreliance on active institutional controls after closure; passive controls after closure; natural resource areas; and design of disposal systems to allow future recovery of wastes.

The guidelines will be revised as necessary after the adoption of final regulations by the EPA.

The implementation of 40 CFR Part 191, Subpart B is required by 10 CFR 60.112. 10 CFR 60.113 establishes minimum conditions to be met for engineered components and ground-water flow; specifically: (1) Containment of radioactive waste within the waste packages will be substantially complete for a period to be determined by the NRC taking into account the factors specified in 10 CFR 60.113(b) provided that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; (2) the release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the NRC, provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste originally emplaced in the underground facility that remains after 1,000 years of radioactive decay; and (3) the geologic repository shall be located so that pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the NRC.

The guidelines will be revised as necessary to ensure consistency with 10 CFR Part 60.

Appendix II—NRC and EPA Requirements for Preclosure Repository Performance

Under proposed 40 CFR Part 191, Subpart A—*Environmental Standards for Management and Storage*, Section 191.03, "Standards for Normal Operations", specifies: (1) That operations should be conducted so as to reduce exposure to members of the public to the extent reasonably achievable, taking into account technical, social, and economic considerations; and (2) that, except for variances permitted for unusual operations under Section 191.04 as an upper limit, normal operations shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public due to: (i) operations covered by 40 CFR Part 190, (ii) planned discharges of radioactive material to the general environment from operations covered by this Subpart, and (iii) direct radiation from these operations; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, or 25 millirems to any other organ.

The guidelines will be revised as necessary after the adoption of final regulations by the EPA.

The implementation of 40 CFR Part 191, Subpart A and 10 CFR Part 20 is required by 10 CFR 60.111. 10 CFR 60.111 also specifies requirements for waste retrieval, if necessary, including considerations of design, backfilling, and schedule. 10 CFR Part 20 establishes (a) exposure limits for operating personnel and (b) permissible concentrations of radionuclides in uncontrolled areas for air and water. The latter are generally less restrictive than 40 CFR 191, Subpart A, but may be limiting under certain conditions (i.e., if used as a maximum for short durations rather than annual averages).

The guidelines will be revised as necessary to ensure consistency with 10 CFR Part 60.

Appendix III—Application of the System and Technical Guidelines During the Siting Process

1. This appendix presents a table that specifies how the guidelines of Subparts C and D are to be applied at the principal decision points of the siting process. The decision points, as referenced in the table, are defined as follows:

"Potentially acceptable" means the decision point at which a site is identified as potentially acceptable.

"Nomination and recommendation" means the decision point at which a site is nominated as suitable for characterization or recommended as a candidate site for characterization.

"Repository site selection" means the decision point at which a site is recommended for the development of a repository.

2. The findings resulting from the application of a disqualifying condition for any particular guideline at a given decision point are denoted in the table by the numeral 1 or 2. The numerals 1 and 2 signify the types of findings that are required and are defined as follows:

"1" means *either* of the following:

(a) The evidence does *not* support a finding that the site is disqualified.

or

• Geochemical properties of minerals as related to radionuclide transport.

Section 960.4-2-3 Rock characteristics.

Description of the geologic and geomechanical characteristics of the site, in context with the geologic setting, in order to estimate the capability of the host rock and surrounding rock units to accommodate the thermal, mechanical, chemical, and radiation stresses expected to be induced by repository construction, operation, and closure and by expected interactions among the waste, host rock, ground-water, and engineered components of the repository system. The types of information to support this description should include—

• Approximate geology and stratigraphy of the site, including the depth, thickness, and lateral extent of the host rock and surrounding rock units.

• Approximate structural framework of the rock units and any major discontinuities identified from core samples.

• Approximate thermal, mechanical, and thermomechanical properties of the rocks, with consideration of the effects of time, stress, temperature, dimensional scale, and any major identified structural discontinuities.

• Estimates of the magnitude and direction of in situ stress and of temperature in the host rock and surrounding rock units.

Section 960.4-2-4 Climatic changes.

Description of the climatic conditions of the site region, in context with global and regional patterns of climatic changes during the Quaternary Period, in order to project likely future changes in climate such that potential impacts on the repository can be estimated. The types of information to support this description should include—

• Expected climatic conditions and cycles, based on extrapolation of climates during the Quaternary Period.

• Geomorphology of the site region and evidence of changes due to climatic changes.

• Estimated effects of expected climatic cycles on the surface-water and the groundwater systems.

Section 960.4-2-5 Erosion.

Description of the structure, stratigraphy, and geomorphology of the site, in context with the geologic setting, in order to estimate the depth of waste emplacement and the likelihood for erosional processes to uncover the waste in less than one million years. The types of information to support this description should include—

• Depth, thickness, and lateral extent of the host rock and the overlying rock units.

• Lithology of the stratigraphic units above the host rock.

• Nature and rates of geomorphic processes during the Quaternary Period.

Section 960.4-2-6 Dissolution.

Description of the stratigraphy, structure, hydrology, and geochemistry of the site, in context with the geologic setting, to delineate the approximate limits of subsurface rock dissolution, if any. This description should include such information as the following:

• The stratigraphy of the site, including rock units largely comprised of water-soluble minerals.

• The approximate extent and configuration of features indicative of dissolution within the geologic setting.

Section 960.4-2-7 Tectonics.

Description of the tectonic setting of the site, in context with its geologic setting, in order to project the tectonic stability of the site over the next 10,000 years and to identify tectonic features and processes that could be reasonably expected to have a potentially adverse effect on the performance of the repository. The types of information to support this description should include—

• The tectonic history and framework of the geologic setting and the site.

• Quaternary faults in the geologic setting, including their length, displacement, and any information regarding the age of latest movement.

• Active tectonic processes, such as uplift, diapirism, tilting, subsidence, faulting, and volcanism.

• Estimate of the geothermal gradient.

• Estimate of the regional in situ stress field.

• The historical seismicity of the geologic setting.

Section 960.4-2-8 Human interference.

Section 960.4-2-8-1 Natural resources.

Description of the mineral and energy resources of the site, in order to project whether past or future exploration and recovery could have a potentially adverse effect on the performance of the repository. The types of information to support this description should include—

• Known occurrences of energy and mineral resources, including ground water.

• Estimates of the present and projected value of these resources compared with resources contained in other areas of similar size in the geologic setting.

• Past and present drilling and mining operations in the vicinity of the site.

Section 960.4-2-8-2 Site ownership and control.

Description of the ownership of land for the geologic-repository operations area and the controlled area, in order to evaluate whether the DOE can obtain ownership of, and control access to, the site. The types of information to support this description should include—

- Present land ownership.

Section 960.5-2-1 Population density and distribution.

Description of the population density and distribution of the site region, in order to identify highly populated areas and the nearest 1 mile by 1 mile area having a population greater than 1,000 persons. The types of information to support this description should include—

- The most-recent U.S. census, including population composition, distribution, and density.

Section 960.5-2-2 Site ownership and control.

Description of current ownership of land, including surface and subsurface mineral and water rights, in order to evaluate whether the DOE can obtain control of land within the projected restricted area. The types of information to support this description should include—

- Present land ownership.

Section 960.5-2-3 Meteorology.

The meteorological setting, as determined from the closest recording station, in order to project meteorological conditions during repository operation and closure and their potential effects on the transport of airborne emissions. The types of information to support this description should include—

- Wind and atmospheric-dispersion characteristics.
- Precipitation characteristics.
- Extreme weather phenomena.

Section 960.5-2-4 Offsite installations and operations.

Description of offsite installations and operations in the vicinity of the site in order to estimate their projected effects on repository construction, operation, or closure. The types of information to support this description should include—

- Location and nature of nearby industrial, transportation, and military installations and operations, including atomic energy defense activities.

Section 960.5-2-5 Environmental quality.

Description of environmental conditions in order to estimate potential impacts on public health and welfare and on environmental quality. The types of information to support this description should include—

- Applicable Federal, State, and local procedural and substantive environmental requirements.
- Existing air quality and trends.
- Existing surface-water and ground-water quality and quantity.
- Existing land resources and uses.
- Existing terrestrial and aquatic vegetation and wildlife.
- Location of any identified critical habitats for threatened or endangered species.
- Existing aesthetic characteristics.
- Location of components of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Land.
- Location of significant State or regional protected resource areas, such as State parks, wildlife areas, or historical areas.
- Location of significant Native American resources such as major Indian religious sites, or other sites of unique cultural interest.

Section 960.5-2-6 Socioeconomic impacts.

Description of the socioeconomic conditions of the site, including population density and distribution, economics, community services and facilities, social conditions, and fiscal and government structure, in order to estimate the impacts that might result from site characterization and from the development of a repository at that site. The types of information to support this description should include—

- Population composition, density, and distribution.
- Economic base and economic activity, including major sectors of local economy.
- Employment distribution and trends by economic sector.
- Resource usage.
- Community services and infrastructure including trends in use and current capacity utilization.
- Housing supply and demand.
- Life style and indicators of the quality of life.
- Existing social problems.
- Sources of, and trends in, local government expenditures and revenues.

Section 960.5-2-7 Transportation.

Description of the transportation facilities in the vicinity of the site in order to evaluate existing or required access routes or improvements. The types of information to support this description should include—

- Estimates of the overall cost and risk of transporting waste to the site.

• Description of the road and rail network between the site and the nearest Interstate highways and major rail lines; also, description of the waterway system, if any.

• Analyses of the adequacy of the existing regional transportation network to handle waste shipments; the movement of supplies for repository construction, operation, and closure; removal of nonradioactive waste from the site; and the transportation of the labor force.

• Improvements anticipated to be required in the transportation network and their feasibility, cost, and environmental impacts.

• Compatibility of the required transportation network improvements with the local and regional transportation and land-use plans.

• Analysis of weather impacts on transportation.

• Analysis of emergency response requirements and capabilities related to transportation.

Section 960.5-2-8 Surface characteristics.

Description of the surface characteristics of the site, in order to evaluate whether repository construction, operation, and closure are feasible on the basis of site characteristics that influence those activities. The types of information to support this description should include—

• Topography of the site.

• Existing and planned surface bodies of water.

• Definition of areas of landslides and other potentially unstable slopes, poorly drained material, or materials of low bearing strength or of high liquefaction potential.

Section 960.5-2-9 Rock characteristics.

Description of the geologic and geomechanical characteristics of the site, in context with the geologic setting, in order to project the capability of the host rock and the surrounding rock units to provide the space required for the underground facility and safe underground openings during repository construction, operation, and closure. The types of information to support this description should include—

• Depth, thickness, and lateral extent of the host rock.

• Stratigraphic and structural features within the host rock and adjacent rock units.

• Thermal, mechanical, and thermomechanical properties and constructibility characteristics of the rocks, with consideration of the effects of time, stress, temperature, dimensional scale, and any major identified structural discontinuities.

• Fluid inclusions and gas content in the host rock.

• Estimates of the magnitude and direction of in situ stress and of temperature in the host rock.

Section 960.5-2-10 Hydrology.

Description of the hydrology of the site, in context with its geologic setting, in order to project compatibility with repository construction, operation, and closure. The types of information to support this description should include—

• Surface-water systems, including recharge and runoff characteristics, and potential for flooding of the repository.

• Nature and location of aquifers, confining units, and aquitards.

• Potentiometric surfaces of aquifers.

• Hydraulic properties of geohydrologic units.

Section 960.5-2-11 Tectonics.

Description of the tectonic setting of the site, in context with the regional setting, in order to estimate any expected effects of tectonic activity on repository construction, operation, or closure. The types of information to support this description should include—

• Quaternary faults.

• Active tectonic processes.

• Preliminary estimates of expected ground motion caused by the maximum potential earthquake within the geologic setting.

Appendix D

Idaho National Engineering Laboratory

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.

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.

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
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 criticality 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	10CRF60.131(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	10CRF60. 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	10CRF60.135	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	10CRF60.135	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	40CRF191. 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.

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