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ACTION

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

January 9, 1989

Note to: HLGP Section Leaders

From: R. Ballard

Subject: Review of Draft Technical Position on Retrieval Demonstration

Attached for your review is a draft technical position entitled "Retrieval Demonstration During Site Characterization."

Forward your comments to P. Justus, who will combine them into a single response. Your comments are needed by January 25.

Ron Ballard
R. Ballard

cc: file

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

ACTION

DEC 30 1988

MEMORANDUM FOR: John J. Linehan, Director
Repository Licensing Project Directorate
Division of High-Level Waste Management

Ronald L. Ballard, Chief
Geosciences & Systems Performance Branch
Division of High-Level Waste Management

James R. Wolf, Attorney
Office of the General Counsel

Melvin Silberberg, Chief
Waste Management Branch, RES

THRU: Joseph O. Bunting, Chief
Engineering Branch
Division of High-Level Waste Management

FROM: Richard A. Weller, Section Leader
Engineering Branch
Division of High-Level Waste Management

SUBJECT: INTERNAL DRAFT OF TECHNICAL POSITION ENTITLED RETRIEVAL DEMONSTRATION DURING SITE CHARACTERIZATION

Enclosed for your review and comment is an internal draft of the technical position entitled: "Retrieval Demonstration During Site Characterization." The draft was prepared according to the TP schedule laid out in the Commission Paper Secy-88-285, which calls for an internal draft by December 1988.

We would like to receive your comments [redacted] that we can incorporate them in the TP. Our target date for a public comment draft is March 1989. Please inform your staff that time spent on review of this TP be charged to PPSAS No. 411133, Tac No. L61323. If you have any questions, please direct them to Naiem Tanious on extension 20538.

Richard A. Weller

Richard A. Weller, Section Leader
Engineering Branch
Division of High-Level Waste Management

Enclosure:
As Stated

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DRAFT TECHNICAL POSITION

~~GUIDANCE FOR DETERMINATION OF LEVEL OF~~
~~RETRIEVAL~~ DEMONSTRATION ~~NEEDED~~ of Retrievability
REQUIRED DURING
SITE CHARACTERIZATION

Manuscript Completed: December 30, 1988
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1.0 INTRODUCTION

1.1 Purpose

This NRC Technical Position is intended to provide guidance on the needed level of demonstration(both physical and numerical, and related studies that should be planned and carried out during site characterization)to adequately support a reasonably-complete license application. Retrieval of previously emplaced nuclear waste is a pre-closure performance objective (10 CFR 60.111(b)), as such retrievability is a basic design consideration which must be addressed early and cannot be postponed to later stages of the repository design, as will be shown in this technical position.

1.2 Scope

This Technical Position suggests certain guidelines for site characterization data which is collected to assess the adequacy of the site as well as to support a construction design whose major goal is to assure retrievability of waste, in accordance with regulatory requirements. Retrieval and retrievability have been the subject of many reports, and meetings between NRC and DOE, however questions on level of demonstration of retrievability remain, thus there is a need for additional guidance. This guidance is considered timely, especially with the recent publication of the Yucca Mountain Site Site Characterization Plan (SCP) and the accompanying Coceptual Design Report (CDR).

The observations made in this technical position are drawn from rationale for retrieval articulated in 10 CFR 60 ~~and~~ in the Statements of Consideration supporting it. ~~Also~~ with consideration of data needs, schedule requirements for licensing and waste emplacemnt, present level of retrieval system development described by the DOE, and information and concepts from several workshops, meetings pertinent to retrieval. The NRC staff recognize the complexity of designing a repository to emplace the waste as well ~~as to~~ retreive it later, if public safety requires it, however it is hoped with the position taken in this paper, the site characterization program and design will go forward to satisy this basic performance objective. Retrieval and retrievability ~~are~~ strongly impacted by site characteristics and by developing workable, safe retrieval systems, as such retrievability could be precluded by inadequate consideration of both.

Retrievability cannot be adequately assured through equipment development alone, in the absence of detailed site data. The questions addressed in this technical position are what levels of data and demonstrations are needed, and when in the design and licensing schedule is it necessary to fulfill these needs. This technical position will discuss the data and guidelines for computer simulations, in situ testing, physical demonstrations and operational studies that are pertinent to resolution of retrieval and retrievability issues.

1.3 General Background

The Nuclear Waste Policy Act (NWPA) passed by the United States Congress in 1982, and amended in 1987, charges the Department of Energy (DOE) with the siting, selection, design, construction, operation and decommissioning of a high-level nuclear waste geologic repository. The Act also charges the Nuclear Regulatory Commission (NRC) with regulating the disposal of nuclear waste in these repositories. As currently authorized, only the Yucca Mountain site, will be characterized to determine its suitability for storing and isolating nuclear waste. If, after successful completion of the site characterization program, the site is found suitable, the DOE will apply for a license from the NRC to construct a geologic repository to permanently store and isolate high-level nuclear waste.

The NWPA and the Code of Federal Regulations, 10 CFR 60, require that the nuclear waste geologic repository operations area be designed to preserve the option of retrieving the waste, should retrieval become necessary. Additionally, the Environmental Protection Agency (EPA) requires in their rule 40 CFR 191 that the disposal systems be selected so that removal of most of the waste is not precluded.

The underground facility may remain open for a period which can be as long as 84 years: 10 years for construction, 24 years for emplacement of waste, and 50 years for retrieval. This is a fairly long period, even by underground mining standards. during this period the waste emplaced in major portions of the facility may be classified as retrievable. Retrieval is a series of major underground operations (the rule estimates retrieval will approximately take the same time as that needed for emplacement) which are inherently more complicated than emplacement. It should be expected that retrieval will likely (unless ordered early) take place in an environment that is both more dangerous and hostile to personnel because of deteriorations in rock conditions and opening support systems, elevated air and rock temperatures, and potential exposures to radiation.

The NRC will require retrieval to protect public health and safety in the event the site, design, or operations proves to be unsuitable. Based on performance confirmation data, the NRC will determine whether the repository system or subsystem (natural or engineered) has failed (or is expected to fail) to meet the performance criteria. If such failure is determined at any time during the preclosure period ~~by completing~~ from an NRC review of the performance data, the NRC may direct the DOE to retrieve the waste.

The DOE could retrieve waste for its own reasons without being directed by the NRC. Such activity, however, must be carried out under 10 CFR part 20, other applicable NRC regulations governing movement of waste, as well as parts 60.112 and 113 requirements covering postclosure overall system performance and postclosure particular barriers performance for the remaining waste (if any).

It should be noted that the NRC retrievability provision in Part 60 is only intended to protect the public radiological health and safety.

2.0 REGULATORY BACKGROUND

Waste retrieval required under the authority of the Nuclear Regulatory Commission is covered in 10 CFR 60. Aspects of waste movements for any purpose also are covered in 10 CFR 20. Other pertinent regulations and documents to retrieval and retrievability are mentioned separately. This Section provides only a summary and not exact quotes, the reader is referred to the appropriate references for the full text.

2.1. Provisions of 10 CFR 60

2.1.1 Performance Objectives

The preclosure performance objectives of the geologic repository call for:

(1) designing the geologic repository operations area so that protection against radiation exposures and releases of radioactive material is provided (10 CFR 60.111(a), and 10 CFR 20), ~~and~~

(2) designing the geologic repository operations area to preserve the option of waste retrieval (10 CFR 60.111(b)).

Retrieval of any or all the emplaced waste can start at any time up to 50 years (10 CFR 60.111(b)(1)) after waste emplacement operations had been initiated (unless a different time period is approved or specified by the Commission on a case by case basis). The retrieval requirement does not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geolgic repository operations area prior to the end of the period of design for retreivability. The rule further states that a reasonable schedule for retrieval is one that would permit retrieval in about the same time devoted to construction and waste emplacement.

2.1.2 Design Criteria

The following two items are critical aspects of repository design that affect retrievability: (1) coupled thermal-mechanical-hydrological-chemical (T-M-H-C) response of the waste packages and the host rock in their immediate vicinity, as it may affect integrity of the waste packages during retrieval, as well as the ability of men and machinery to access and safely remove the waste packages, (2) underground ventilation, as it may affect enviromental conditions and control of any radioactive release. Both are addressed implicitly and explicitly in the 10 CFR 60.

Design criteria explicitly pertaining to the waste package, rock mass response, and ventilation are found in 10 CFR 60.135, 130, 131, 132, and 133. These include:

(1) "Waste Packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval."

(2) "The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of 60.111 (10 CFR 60.133(c)"

(3) "openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained (10 CFR 60.133(e)(1))",

(4) "openings be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding strata (10 CFR 60.133(e)(2)."

The ventilation system shall be designed to:

(1) control the transport of radioactive particulates and gases within, and releases from, the underground facility,

(2) assure continued function during normal operations and under accident conditions; and,

(3) separate the ventilation of excavation and waste emplacement areas, (10 CFR 60.133 (g)).

By including both normal and accident conditions, by referring to Section 111(a) which covers performance at all times through permanent closure, and by not restricting the applicability of any requirements to normal repository operations, the above provisions apply as much to retrieval as to other aspects of operations.

Part 60 further states that the design of the geologic repository operations area shall be in compliance with mining regulations (10 CFR 60.131 (b)(9)). The design will also provide for control of water or gas intrusions (10 CFR 60.133(d)), and assure that the effect of disruptive events such as flooding, fires, and explosions will not spread through the facility (10 CFR 60.133 (a)(2)). Again, these requirements apply during retrieval operations as well.

The design shall also include provisions for instrumentation and control systems (10 CFR 60.131(b)(8)), and shall maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency (10 CFR 60 131(b)(4)).

2.1.3 Retrieval Plans

Retrieval operations will be carried out according to retrieval plans, which are required as part of the Safety Analysis Report (10 CFR 60.21(c)(12)) that is submitted with the license application.

2.1.4 Performance Confirmation

An NRC decision to order retrieval of the waste, or allow permanent closure of the underground facility will most likely be based on the results from the performance confirmation program. This program is not designed to test waste retrieval , but its results may trigger a decision to retrieve. Performnce confirmation will be initiated by the DOE during site characterization and is likely to continue until permanent closure. Performance confirmation includes among other things: "in situ monitoring, laboratory and field testing, and in situ experiments", (10 CFR 60.140(c)). Results from the performance confirmation program will ensure that geotechnical and other parameters used in the repository design are confirmed (10CFR60.141).

2.2 Statements of Considerations to 10 CFR 60

The rationale for the retrievability provisions of 10 CFR 60 and some insight into the relative importance of retrievability and other design provisions may be found in the Statement of Considerations published by the NRC (NUREG-0804). NUREG-0804 states that the additional costs that may occur because of retrievability, is an acceptable and necessary price to pay to assure that the EPA standards will be satisfied. Because of the importance of this reference, the full text is reproduced as Appendix A to this Technical Position.

2.3 Provisions of 10 CFR 20

The radionuclides exposure standards for personnel in the repository restricted and unrestricted areas are covered in 10 CFR 20, and is referenced in 10 CFR 60 including the overall preclosure performance objective in 60.111(a).

2.4 40 CFR 191

The regulations in 40 CFR 191 are promulgated by the EPA and describe the performance requirements for the repository engineered barriers and the geologic setting. It refers to an ability to recover wastes after disposal. This provision would rule out certain disposal options, such as deep-well injection, considered undesirable by EPA. The 40 CFR 191 regulations specify reduction of exposure to the public in the preclosure and postclosure periods.

2.5 NWPA

The NWPA of 1982 and as ammended in 1987 prescribes environmental protection controls for waste disposal. NWPA requires retrievability for control of adverse impacts to the environment, which is considered the same as the public health and safety in 10 CFR 60.

3.0 TECHNICAL POSITION

3.1 Inclusion of Waste Removal in Retrieval Plans

In their position on retrievability and retrieval, the DOE has distinguished waste removal from waste retrieval, as retrieval being triggered by accumlation of evidence of a threat to the public health and safety or the environment, and removal being any efforts to remove, extract, or relocate any portion of the emplaced waste for testing, inspection related to performance confirmation, redistribution of inventory for ventilation reasons, or similiar operational considerations not related to public health and safety. The NRC does not contest this terminology introduced by the DOE. However this separation is ficticuous because the two operations are physically almost identical, and furthermore it is probably impractical to design, construct, and implement two entirely different waste removal systems, one for "retrieval", and the other for "non-retrieval". As a result of using this terminology, these "removal" activites, however large in scope, may not be covered by any plan, retrieval or otherwise. Therefore, it is the NRC staff's position that DOE should either submit plans for waste removal operations, and explicitly describe such plans in the Safety Analyses Report, or include waste removal activities in the required retrieval plans.

3.2 Timing of the Retrieval Demonstrations

Most in-situ testing and demonstrations to establish the "capability to retreive" should be completed prior to the submission of Construction Authorization. It is the view of the NRC staff that further demonstrations and development may be needed to correct specific deficiencies, if any are found, in the technical support submitted for the application for the construction authorization. Such tests and demonstrations would therefore be contemporaneous with repository construction. To the extent that uncertainties in retrieval plans and designs could affect basic aspects of repository construction, and to the extent that some construction (such as completed excavation) may be irrevocable whether unfavorable to retrieval or not, the deficiencies should be corrected and questions about the retrieval system at the time of repository construction should be answered. At the very least, all aspects of retrievability that could potentially be limited by site characteristics (as expressed whether in the retrieval system or in repository construction) should be resolved within the scope of site characterization prior to construction authorization. Therefore, for these site-specific aspects of retrievability, the applicable period of site charcterization should end prior to the application for construction authorization

3.3 Modelling Strategy For Retrieval Demonstrations

To predict conditions during retrieval, models should be subjected through an iterative procedure of model validation with increasing levels of in situ measurements. The process suggested in the Rationale Section is to build confidence in the understanding of the range of tuff response as well as its predictability by extensive comparison of the behavioral models to the rock mass response to excavation under a wide range of conditions. It is fully expected that adjustments in properties and/or constitutive models will be necessary during this comparative stage, and additional testing of the heated block variety or, perhaps, new testing will be required. However, as the interactive approach of comparison of the models to single excavation behavior continues, increased confidence in the ability to predict the response should be obtained.

3.4 In Situ Testing Strategy For Retrieval Demonstrations

In situ testing for retrievability should utilize full-size, multiple-excavations, that are fully instrumented to assess host rock behavior and the performance of drift-support systems, under thermal loading. it is suggested that a practical engineering demonstration approach should be taken by subjecting a large volume of ground to elevated temperature conditions prototypical of the repository. This approch fully tests the predictive ability of the models and the understanding of rock mass behavior, futhermore the approch provides data for other engineering studies required for the repository design.

3.5 Retrieval Systems and equipment demonstrations

3.5.1 Data, studies, and demonstrations to support retrievability should not lag behined the design of the repository systems such that the retrieval system provisions could become "appendages" to the repository system.

3.5.2 Proof-of-Principle and prototypical demonstrations should be part of the site characterization program.

3.5.3 Demonstrations of systems and equipment should be conducted in an underground environment that simulates repository conditions, also these demonstrations should include off-normal conditions.

3.5.4 If components or operations whose failure could preclude retrievability have attributes that are not covered by the construction experience or site characterization data, then the NRC would require a demonstration sufficient to evaluate the reliabilities of such components or operations. In particular, demonstrations of retrieval equipment would most likely be required for items that incorporate new technology or combinations of technology that have not been proven through field use for similar applications. Examples of equipment falling into this category would be the retrieval systems and components used to extract waste packages from boreholes.

4.0 RATIONALE

This section contains the rationale behind the technical position and cover discussions of retrieval demonstrations concepts and terminology, modelling strategy for retrieval demonstrations, in-situ strategy for retrieval demonstration, information needed for adequate assurance of retrievability, and the level of demonstration needed during site characterization.

4.1. RETRIEVAL DEMONSTRATION CONCEPTS AND TERMINOLOGY

The questions of retrievability and advance assurance of retrieval pertinent to licensing introduce new concepts not normally encountered in engineering projects. For purposes of this technical position, the concepts and terminology used herein are defined in the following discussion.

4.1.1 General Goals of Retrievability

The overall goal of 10 CFR 60 is to ensure the health and safety of the public with respect to nuclear waste disposal in a geologic repository. The rule also requires measures to assure the safety of workers involved in waste handling. These goals cannot be assured unless the waste is kept under control at all times. It can be stated that the essence of the regulatory process is to assure this control of the waste. This can be appreciated through the Statements of Consideration to 10 CFR 60 and the language of 10 CFR 60 itself, covered in the previous chapter. Were the waste not retrievable, the decision to leave it in place would, in effect, be irrevocably made merely by the act of emplacement.

The desired waste control takes several forms. During the operational period, direct human control of the waste is possible, through containment. Containment is initially afforded by transportation casks, later by confinement within the waste handling building, and finally, during subsequent transportation, transfer, and emplacement operations, containment is afforded by the waste container itself. However, once the container is emplaced, direct control would be relinquished, unless the waste were fully retrievable.

The regulations provide for some control of the waste after repository closure. During this period, even though direct, human control of the waste is relinquished to the geologic setting, indirect control remains, through the selection and preservation of the geologic setting as an isolating medium. This is permitted to occur only after it is acceptably assured that the geologic setting will provide effective isolation of the waste, and that the waste container will continue to reliably provide containment.

Before any measure of direct control of the waste is relinquished to the geologic setting or to the waste container, the satisfactory performance of the repository system must be assured. Therefore, if waste is to be emplaced, it must be retrievable. Furthermore, if waste is to be retrieved, the retrieval action must present an opportunity for control that is at least equivalent to that of simply leaving the waste in place. Retrievability is, therefore, a critical provision for control of the waste. In a very real sense, retrievability is the ultimate saftey provision in the licensing process and in the design. If the waste is not fully and safely retrievable, then it is out of full and direct control. This must not occur until a decision can be justified to accept the indirect sources of control afforded by the geologic setting and waste container.

4.1.2 "Retrieval" Versus "Retrievability"

In the past, confusion has arisen when the terms "retrieval" and "retrievability" have been used. Recent program guidance from both NRC and DOE have sought to resolve this situation. "Retrieval" refers to the act of physically removing emplaced waste. Retrieval is not mandated in 10 CFR 60 except as considered warranted by the Commission. "Retrievability" refers to the capability to retrieve the waste, and is a regulatory requirement.

4.1.3 Time Periods for Retrieval and Retrievability

The time required for retrieval and retrievability are set forth in 10 CFR 60.111(b)(1) which has been paraphrased by the DOE in Appendix D to the Generic Requirements document (GR) for a geologic repository (DOE document number OGR/B-2). The wording of 10 CFR 60.111(b)(2) has been included in Section 2 herein and is not repeated here. However, several salient points merit special mention.

- Retrievability must be preserved from the time emplacement is initiated until after a Commission review of performance confirmation information. The rule does not define "retrievability period". The 50-year retrievability period following the beginning of waste emplacement that is referred to in the Rule is a design guideline and the Commission could specify a different period for design purposes, whether or not it is requested by the DOE. Regardless, the retrievability period in practice must extend through the Commission's review of the performance confirmation program, or (obviously) until full retrieval is complete.

- Retrieval is to be accomplished on a "reasonable schedule", which is described for illustration purposes as approximately the time required to construct the repository and emplace the waste. There is nothing in 10 CFR 60 that precludes establishing a different retrieval schedule should conditions so warrant. At present, repository construction is projected by the DOE to take 6 years and emplacement an additional 28 years, so that the retrieval schedule for present purposes would be, at most, 34 years after retrieval commences.

- The two points above mean that the design basis, and the <u>current</u> regulatory guidance, are such that retrievability must be maintained for 50 years following the beginning of ~~emplacement~~, and that retrieval would therefore be possible at any time during this interval. Retrieval of the entire waste inventory could theoretically be initiated just prior to the expiration of the 50th year and could require, under present design concepts, as much as an additional 34 years to complete, for a total of 84 years. Therefore "retrievability must be maintained <u>throughout the retrieval period</u> also, which means for 84 years.

The design periods are, in essence, hypothetical. What is significant for licensing is that assurance of retrievability must prevail for a very long period (as compared to most engineering lifetimes) and must encompass retrieval conditions as well as the more-dormant conditions expected for undisturbed, emplaced waste.

In its position on retrieval and retrievability, the DOE has mandated that retrieval would be carried out "as quickly as is safely practicable" (OGR/B-2 Revision 3, p. D-6), the requirement for safety being preeminent. However, the DOE also notes that the period of preparation for retrieval may be lengthly and that retrieval itself may require more time per unit of waste than emplacement (ibid.). Also, the DOE has asserted that there would be no time limit on partial retrieval (retrieval of less that the full waste inventory) if emplacement operations are continuing (ibid.). This portion appears to assume that emplacement and retrieval operations could occur simultaneously.

~~4.1.4~~ <u>"Retrieval" Versus "Removal of Waste</u>

The Rule provides for retrieval as a means to implement and make meaningful the NRC's decision to close or not to close the repository. The DOE presumed that the "retrieval" referred to in the Rule is that which the NRC would require because of "evidence that the health and safety of the public would otherwise be adversely affected by the emplaced waste" (OGR/B-2, revision 3, p. D-3) and if the Commission "has cause to believe that the geologic repository isolation system as planned and implemented will not meet the performance standards and objectives" governing waste disposal. The DOE position also considers the effects on the environment to be the same as the effects on public health and safety (ibid.) so the the provision for "retrieval" called for in Section 122 of the NWPA is also addressed in the DOE position. "Retrieval" could also occur for resource recovery reasons at the discretion of the DOE, subject to applicable NRC regulations and the NWPA. All other waste removal is not considered "retrieval" for purposes of the DOE position.

Certain aspects of waste removal fall under NRC regulations regardless of the purpose and it is likely that many of the activities engaged therein would be identical to similar steps taken for the form of "retrieval" identified by the DOE. Movement of waste within the repository for any reason must conform to applicable regulations. Also, the ability of the repository to meet the performance objectives for the undisturbed waste must not be compromised by waste removal activities, regardless of the purpose for the removal of the waste. Since it is probably impractical and unnecessary to design two entirely different waste removal schemes, on for "retrieval" and one for non-"retrieval", when most of the regulatory standards would be the same for either case, it would appear that some "retrieval" systems and components would be fully operational and would be used occasionally in waste "removal" (testing and inspection related to the performance confirmation program, transferring waste for operational reasons, or other purposes).

The reason for distinguishing waste "removal" and "retrieval" may actually have the most to do with differences in the expectation of off-normal or hostile conditions. Waste movement ("removal") not falling under the DOE's definition of "retrieval" may be expected to take place under normal conditions, with little or no likelihood that off-normal conditions would be encountered, whereas "retrieval", which by the DOE definition would necessarily be accompanied by some perceived threat to health and safety, would be more likely to encounter off-normal conditions. Nonetheless, in neither case could measures for environmental or personnel protection against off-normal conditions be ruled out. Equipment and procedures to support retrievability under 10 CFR 60 should therefore appreciate that off-normal conditions for waste retrieval are the principal, although not exclusive, concern.

With these observations made, this technical position will use the term "retrieval" when removal of the waste is required by the NRC under its regulatory authority. This technical position does not address the need for "retrieval" for resource recovery purposes, except insofar as NRC regulations apply. All other relocation of emplaced waste is referred to as "removal" in this technical position rather than "retrieval", although, as pointed out previously, certain NRC regulations pertaining to waste movement will also apply regardless of nomenclature.

The NRC has neither accepted nor disputed the DOE's concept of "retrieval" as quoted above.

4.1.5 Level of Assurance of Retrievability

Perhaps the most significant questions regarding consideration of retrievability in licensing have to do with how "retrievable" the waste has to be; in other words, What level of retrieval success must be assured before there is adequate justification for issuance of a license? Since projections of retrieval success will be subject to uncertainty, a related question is brought up: To what extent can uncertainties about achieving the projected level of retrieval success be tolerated within the requirements of the regulations? Does the Commission have to have 100 percent assurance that 100 percent of the waste will be "retrievable" in accordance with all the regulatory constraints 100 percent of the time? Or is some lesser degree of assurance acceptable?

The Rule, 10 CFR 60, does not specifically define the extent to which the Commission must be assured of retrievability before a license to emplace waste could be granted. Elsewhere; however, the Rule introduces the concept of "reasonable assurance" with regard to other measures of performance (10 CFR 60.101(a)(2)). Unfortunately, the Rule does not define "reasonable assurance". Therefore, within the context of the discussions herein, "reasonable assurance" of retrievability will be held to be that level of assurance necessary to establish that the design, and retrieval provisions contained in any retrieval plans developed by the DOE, will result in full control of the waste. This control should be in accordance with the performance objectives and safety requirements of 10 CFR 60 until ~~the time of repository decommissioning~~, and in accordance with the provisions of 10 CFR 60 regarding exposures in both restricted and unrestricted areas. It is again emphasized that these performance objectives require retrievability, as well as containment and preservation of the isolation characteristics of the geologic setting, during the preclosure period.

As stated earlier, retrieval can be viewed as the ultimate safety provision in the regulations governing a repository. However, it is also true that retrievability may never be needed; in fact, retrieval is referred to as a "contingency" or "option" in both NRC and DOE documents. Because of this, care must be taken not to acquire the attitude that retrievability need not attain the same level of design as other repository systems with safety or protection goals. Such an attitude could be used to justify deferral of retrieval system designs to some future date, when they would be "worked in" to the repository system as it had evolved at that time. The intent of the regulations seems to require a greater level of assurance than would be expected from add-ons to a pre-existing design. Rather, the process of making design choices and provisions should involve retrievability in concert with other aspects of the operating and safety systems.

Therefore, a design or plan for retrieval must provide a level of protection for workers, the general public, and the environment, equivalent to that which would be required of any other aspect of repository operations. Concepts, designs, demonstrations, and tests documenting retrievability and submitted in support of licensing should therefore be sufficiently comprehensive to establish that all the applicable regulatory requirements will be met.

Since retrieval must take place in accordance with the provisions of 10 CFR parts 60 and 20 regarding safety, containment, isolation, and maintenance of the retrieval option for the unretrieved waste (if any), the retrieval concept should not be considered viable if compliance with these requirements cannot be demonstrated to the satisfaction of the Commission. If such compliance cannot be demonstrated, "retrievability" cannot be said to exist.

~~4.1.6~~ Site-Specific Retrieval System Design Provisions

Those aspects of retrieval and retrievability that are impacted by site conditions must be covered by data collected during site characterization. "Site Characterization" is defined in 10 CFR 60.2, as "the program of research, both in the laboratory and in the field, undertaken to established the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part." The Rule does not restrict the period of site characterization in terms of the licensing schedule. Accordingly, "site characterization" could extend beyond the time of License Application (10 CFR 60.102(d)). However, it is our opinion that the period, during which demonstrations to establish retrievability would occur, should not extend beyond this point. In accordance with 10 CFR 60.24, the license issued by NRC may rest upon (or even be contingent on) information obtained during construction.

It is the intent of this technical position to ascertain what level of demonstrations and related studies should be planned to occur during site characterization to adequately support a reasonably-complete license application. It is the view of this technical position that further demonstrations and development may be needed to correct specific deficiencies, if any are found, in the technical support submitted for the application for the construction authorization. Such tests and demonstrations would therefore be contemporaneous with repository construction. To the extent that uncertainties in retrieval plans and designs could affect basic aspects of repository construction, and to the extent that some construction (such as completed excavation) may be irrevocable whether unfavorable to retrieval or not, the deficiencies should be corrected and questions about the retrieval system at the time of repository construction should be answered. At the very least, all aspects of retrievability that could potentially be limited by site characteristics (as expressed whether in the retrieval system or in repository construction) should be resolved within the scope of site characterization prior to construction authorization.

Therefore, for these site-specific aspects of retrievability, the applicable period of site charcterization should end prior to the application for construction authorization. In support of this, 10 CFR 60.31(a)(3) states that a construction authorization may be issued if the Commission has reasonable assurance that "the site and design comply with the performance objectives and criteria contained in Subpart E of this part", with Subpart E containing the requirement for retrievability embodied in 10 CFR 60.111(b). It is noted that the Construction Authorization may be made conditional, per 10 CFR 60.32(a), and that other parts of 10 CFR 60 describe design update reporting requirements consistent with the data obtained through site characterization activities (10CFR60.18 (g)).

4.2 MODELING STRATEGY FOR RETRIEVAL DEMONSTRATION

In practice, rock mechanics applications to underground construction have been primarily empirical in nature due to the inherent inhomogeneity of the rock mass. In recent years, models (primarily numerical, but also empirical) have been used in an iterative process with observation and instrumentation to build models which can be used confidently in design and performance assessment. In this program, numerical models will be relied upon, due to lack of empirical data for thermally-loaded caverns. Thermally-loaded rock mass is expected to be the dominant underground condition during retrieval operations.

Existing laboratory or empirical data or field observation are used to choose a constitutive model for the rock mass (e.g., equivalent elastic continuum, Mohr-Coulomb plasticity, ubiquitous joint, etc.). Models are "exercised" against in-situ tests in which the loading and thermal conditions for a representative sample of the rock mass can be controlled. A test such as the heated block test can be used for this purpose. The model can then be used for initial predictions of full scale excavation performance. These performance predictions are compared to observations and measurements of opening response. These are generally measurements of rock displacements (drift closure, drift wall movement), but could also be rock or support stress change. The comparisons are, at first, quite simplistic (e.g., a single tunnel under isothermal conditions), but the detail of comparison increases with increasing model confidence to large scale, coupled thermomechanical problems. If a "reasonable" agreement can be achieved from the simpler, well defined problems, the model can be exercised on the increasingly more difficult problems which involve large-scale coupled effects. At any point in the iterative process, if the comparison is poor, several options should be examined:

(1) re-examine rock mass properties through lab or in situ testing;

(2) Re-examine the constitutive model in use, (this may require additional lab or in situ testing; or may be determined from physical observation);

(3) re-examine the model itself to assure proper operation; or

(4) perform additonal underground measurement for further comparison.

The process suggested here is to build confidence in the understanding of the range of tuff response as well as its predictability by extensive comparison of the behavioral models to the rock mass response to excavation under a wide range of conditions. This type of approach requires flexibility in the testing plan as opposed to a rigidly defined set of tests developed prior to any excavation.

The present in situ testing at G-Tunnel as well as laboratory information has provided thermomechanical properties for welded tuff. The results have lead to the choice of two preliminary constitutive models for the Topopah Springs formation:

(a) an elastic continuum with "equivalent" rock-mass elastic properties; and

(b) a "ubiquitous" or "compliant" joint model - both are continuum representations of a joint rock mass. These two forms of continuum joint representation are distinctly different, as the complaint joint model attempts to account for joint spacing and stiffness through a constitutive law.

These preliminary models of the behavior of welded tuff can be initially examined in detail through comparison against a controlled thermomechanical field test such as the heated block test (Zimmerman et at., 1986). Assuming the model(s) can be verified from this controlled test, it can then be used for comparison to room-scale response of the excavations in the ESF. Initially, the model can be compared to the many measurements of displacement which will be obtained during normal monitoring of the construction of the ESF drifts. These excavations are single drifts of simple cross-section, and will supply a good initial test case. Since these drifts will pass through a variety of rock conditions (particularly those that will explore the boundary fault structures), the comparison of the models will provide a simple means of documenting the range of in-situ properties required to describe the Topopah Springs response. It is fully expected that adjustments in properties and/or constitutive models will be necessary during this comparative stage, and additional testing of the heated block variety or, perhaps, new testing will be required. However, as the interactive approach of comparison of the models to single excavation behavior continues, increased confidence in the ability to predict the response should be obtained.

To fully test the predictive ability of the models and the understanding of rock mass behavior, the test configuration needs to subject larger volumes of rock to conditions-similar to those which will be found in the repository. This can be accomplished by conducting a multiple-excavation test with full-scale emplacement drifts. Initially, this test is aimed at monitoring isothermal excavation interations; however, the facility can also be used as a laboratory for simulating full-scale repository response. Heater experiments in varying configurations can be used, and the entire facility can be heated to simulated repository conditions. This will allow examination of important preclosure response of rock reinforcement as well as the extent and character of excavations and thermal disturbance. The facility can further be used for confirmation testing during repository development when heating effects are examined for time spans on the order of the retrieval period.

4.3 IN-SITU TESTING STRATEGY FOR RETRIEVAL DEMONSTRATION

One of the geotechnical questions which exists at the Yucca Mountain site is whether openings can be excavated which will remain stable under repository conditions over the retrieval period without resorting to extraordinary means of support. In addition, it needs to be demonstrated that the response of the rock mass to excavation and thermal loading is predictable using empirical, analytic, and numerical approaches. The need for predictability arises from the lack of empirical data regarding thermally-loaded excavations.

The argument was put forward earlier in Section that the logical approach to in-situ testing at Yucca Mountain is an interactive approach--i.e., one in which the gross response of the rock mass is determined under the varying rock mass conditions which are likely to be encountered within the actual repository. This approach is based heavily on the need to demonstrate the response of the rock mass and excavations under conditions typical of the proposed repository environment. This philosophy lessens the requirement for numerical models to predict performance based only on point tests and small-scale thermomechanical loadings. The development of a "validated" numerical model will provide the ability to extrapolate the rock mass response to different thermal loadings or rock conditions. This is required because large-scale thermomechanical tests cannot be conducted under all possible geologic conditions present in the ES.

With this approach in mind, the following testing has four components: (1) constitutive model testing; (2) exploration drifting; (3) multiple, full-scale repository excavation at ambient temperature; and (4) multiple excavation at elevated temperature.

An integral part of this testing is the verification of a constitutive (i.e., yield or strength) model for the rock mass and the testing and verification of rock mass response models. The ultimate objectives are:

(1) to demonstrate the ability to construct stable repository openings under variable ground conditions and to determine the rock support requirements under ambient and elevated temperature;

(2) to verify a constitutive model (i.e., strength criterion) which can reasonably encompass the variable geologic structures and temperature conditions; and

(3) to demonstrate the predictability of rock mass response under variable ground conditions and thermal loading histories.

4.3.1 Emplacement Borehole Drilling

There is little question of the ability to drill and emplace waste in the vertical-emplacement mode described earlier as one of the options for waste emplacement. Holes may require cleaning prior to emplacement, but there is no reason to expect massive instability. There is; however, little experience in the area of long horizontal-hole drilling. Although major problems are not expected in drilling and lining these holes, it is nonetheless important to conduct trial runs of drilling, liner emplacement, hole outfitting and mock canister emplacement. During drilling, records need to be kept on advance rate, fluid injection volumes, and problem areas. After drilling is complete, the hole needs to be examined with a videotaping borescope, a caliper log and directional survey need to be run. This can be followed by hole outfitting and emplacement testing and documentation.

4.3.2 Drift and Borehole Stability at Elevated Temperature

Perhaps the least understood geomechanical question in repository design is the long-term thermomechanical response of the underground openings. The current 50-year retrievability period requires that the various drifts and emplacement boreholes be maintained and stable over this time.

It is necessary to show that the combination of thermal loading density and excavation-induced stress do not result in excessive yield of the rock mass and instability of the openings during the retrieval phase for the suggested CDSCP gross thermal loading. It is also necessary to demonstrate that the response of the rock mass and drift support is predictable with a reasonable degree of confidence. The following two approaches have been taken by designers to determine the allowable gross thermal loading.

1. Use laboratory thermal properties and laboratory elastic properties reduced by some factor to account for jointing as input to a thermoelastic code. Determine the combined excavation and thermal stresses for a given gross thermal load and compare them to a value for the in-situ strength of the rock mass. The value for in-situ strength is based on some reduction factor from the uniaxial compressive strength, or on a yield criterion such as that proposed by Hoek and Brown (1989).

2. The second approach is similar to the first, with the exception that the numerical model embodies the yield criterion as a form of plasticity. The stability of the opening is determined numerically and is based on the resulting yield zone rather than an explicit calculation of rock strength.

Both approaches have been examined for the Yucca Mountain site (Johnstone et al., 1984), but have yet to be verified from field experience. The approach suggested here is to determine the stability of the emplacement holes by simply subjecting them to the design temperature and stress conditions while monitoring their mechanical and thermal response. Models of the rock mass response can be validated against these data.

Although a room-scale heating test is mentioned in the CDSCP, Chapter 8.3 (U.S. DOE, 1988), no discussion is given. It is not felt that single full-scale heater tests (e.g., Stripa) provide data of sufficient breadth to validate thermomechanical codes. We see a significant problem with confident application of room-scale design models whose validation is based on single heater tests which thermally load only small blocks of ground that are highly confined (kinematically). Again, it is suggested that a practical engineering demonstration approach be taken to this problem by subjecting a large volume of ground to elevated temperature conditions prototypical of the repository. The rooms and pillar from the multiple excavation test provide an excellent geometry for conducting a room-scale thermomechanical test. Electrical heaters can be used to provide the thermal loading which is equivalent to (and surpass) the design gross thermal loading. The instrumentation (with supplemental temperature sensing and compensation) can be used to monitor the test.

4.3.3 Analysis of Data

At the completion of the single and multiple-excavation tests, the following should be accomplished:

(1) definition of a constitutive model (i.e., yield function) for the rock mass;

(2) determination of the range in rock mass properties required to account for range in measured data through the various intraflow structures;

(3) identification and validation of numerical model(s) suitable for geomechanics design in tuff;

(4) quantification of confidence (i.e., predictability) in the modeling capabilities;

(5) determination of the conservatism in the rock support design for ambient temperature applications and establishment of opening stability;

(6) determination of the extent of the excavation-induced disturbed zone; and

(7) at least the short-term performance of seals, backfill and drainage under thermal loading.

The analysis of the data from this test attempts to extend these conclusions to the thermomechanical behavior of the rock mass as well.

4.3.4 Constitutive Model Definition and Model Validation

The constitutive model, or yield function, is determined primarily through back analysis of displacements of the openings and pillar under excavation and thermally-induced load. The validated codes from the multiple excavation test will be used to examine the thermomechanical test results. This will involve a comparison of the displacements at mpbx and deflectometer anchorage locations and temperature at thermocouple locations with displacement temperature estimates from the model. A parametric analysis of the data using a range of rock-mass thermal properties will be required to bound the field data. Coupled effects such as temperature dependence of the thermal and elastic properties may be required. From these results, the confidence interval and best-fit properties can be determined.

The stability of the room and emplacement boreholes can be documented from displacement measurements, acoustic emission output, rock support performance, and visual observation.

Displacement data plotted as a function of time and radial distance will indicate the extent of yield and the extent of time-dependent behavior. The acoustic emission system will locate the position of noise generated by crack propagation and/or shearing along existing fractures. These phenomena have been associated with stable yield as well as violent instability (rockburst). There is no definitive method for relating the energy and frequency content of the emissions to the stability of the openings; however, a qualitative assessment can bee made. Identification of dislodged blocks, opening of fractures, etc. provide a qualitative measure of the stability. Examination of the large diameter emplacement borehold surface using a high-temperature borescope will indicate any progressive instability. Both the Stripa and NSTF testing used borescopic examination and photography for determination of borehole stability. Periodic pull tests on rock-bolts will indicate whether deterioration of the resin (or grout bonding) with temperature is occurring. Rockbolt load cells will also indicate whether slippage and decrease in the bond strength results from higher temperature.

The approach for the in-situ testing suggested here. This figure illustrates an iterative procedure aimed at resolving the information needs through five basic components.

1. Monitoring of the mechanical response of shafts and lateral excavations in lithophysae-poor (TSW_2) and lithophysae-rich (TSW_1) tuff. Establish the ground support requirements under non-thermal conditions.

2. Instrumented exploration drifts to the boundary faults to determine variability of rock mass response as well as fault stability under seismic load.

3. Development of full scale repository openings which may be used to study the pre-closure thermomechanical response of the rock mass at expected repository conditions, and to verify ability to meet design criteria.

4. In situ determination of sensitive thermal and mechanical properties.

5. Testing and verification of a constitutive model for welded tuff; establishment of the conservatism in the modeling approach.

~~4.4~~ INFORMATION NEEDED FOR ADEQUATE ASSURANCE OF RETRIEVABILITY

4.4.1 Systems and Components Important to ~~Retrievability~~

In Section ~~3.4~~, Level of Assurance of Retrievability, it was shown that various regulatory requirements, besides the ones requiring the ability to remove the waste, ~~will~~ be satisfied in a design that truly incorporates retrievability. To establish that the waste "is retrievable" it must therefore be shown that the proposed retrieval system will accomplish the following:

- Establish suitable environmental conditions for retrieval.
- Attain access to panel and emplacement drifts.
- Attain access to emplacement sites (waste package locations).
- Assure personnel and public radiological safety through appropriate monitoring, surveys, shielding and ventilation measures, before, during, and following actual retrieval operations.
- Contact, grasp, and withdraw waste packages and any radioactive material or debris that may have accrued from waste storage or retrieval, with an acceptable expectation of success.
- Safely transport to the surface the waste containers and any radioactive material or debris recovered, while maintaining containment.
- Provide adequate waste-handling capabilities for retrieved waste (both underground and on the surface) such that safety, containment, and any continuing repository operations are not adversely affected.

- Assess the post-retrieval radiological condition of the former emplacement sites and take whatever preventive, as well as remedial, action is most effective for protection of public health and safety.

- Decontaminate retrieval equipment as appropriate, and control and properly dispose of all decontamination effluents.

- Assure continued containment, isolation, and retrievability of the remaining waste inventory.

- Accomplish retrieval in the time specified as necessary under the circumstances requiring retrieval.

It must be shown that each of these objectives will be satisfied if claims of "retrievability" are to be credible. For example, it is not sufficient to merely indicate a high probability that remote access to waste packages will be possible, if adequate protection of public health and safety requires that all packages targeted for retrieval must positively be removed, and if overcoming a failure to gain remote access could compromise containment and retrievability of the waste. In such a case it must be shown that access and removal of all waste would not require measures that could compromise safety and containment, or preclude retrievability. A considerable level of modeling followed by realistic demonstrations would be needed to provide reasonable assurance of retrievability in this case.

In order to establish retrievability, it is necessary to consider the range of parameters, both site-specific and non-site-specific, that impact the assurances itemized above.

Some categories of systems, components and parameters that will be crucial to the retrievability of waste are as follows:

- Drift stability (ground support) needed to establish and maintain safe access to and from emplacement sites.

- Borehole and liner configuration, stability, and construction

- Retrieval equipment involved in the physical location, contact, grasping, withdrawal, and transportation of the waste.

- Method and records of emplacement; emplacement configuration; characteristics of the waste and its contianer.

- Ventilation and ability to establish the necessary environment for retrieval, including contribution to control of rock mass behavior, as applicable.

- Anticipation of, and development of procedures for, normal and off-normal conditions together with consideration of post-retrieval consequences.

- Surveys, shielding, inspection, and monitoring of releases, drift and emplacement hole conditions, and other parameters before, during, and after retrieval operations and conditions.

- Handling, transportation, and interim storage of waste materials, including possible radioactive debris or materials accruing from the retrieval process, and all effluents from retrival, including decontamination effluents and ventilation air.

- Decontamination and maintenance procedures.

- Anticipated and unanticipated processes and events.

4.4.2 Assessment of Systems and Components

The systems, activities, and components above will be reviewed by the NRC to determine if the design truly presents retrievability. Due to the complex and unprecedented nature of some of the systems and activities required in retrieval, the analyses conducted by the DOE and the reviews performed by the NRC must be both thorough and conservative.

Test programs, construction experience, and ESF operational experience will constitute a data base from which development of retrieval concepts, and assessments of retrievability, may be begun. The retrieval concepts must encompass the full range of conditions and circumstances that will be involved, so that relevant and meaningful assessments of retrievability can be made. The follwoing, in our opinion, are minimum requirements that have relevance to site conditions. Some are entirely site-specific and a few are indirectly site-specific in that they rely only partially on site data.

- Rock Mass Characteristics

  - strength and defomability, under repository-induced conditions, and at various levels of confinement corresponding to pillar interiors, drift walls, and contact areas with borehole liners

  - porosity and level of saturation, both initially and at the time of retrieval operations

  - thermal properties -- ability to conduct and store heat, and transfer it to passing ventilation

- geochemical environment and variations

- hydrogeological environment and variations

- in situ and induced stresses, both mechanical and thermomechanical, including the effects of pore pressures, if any

- strength, deformability, occurrence, and hydrologic characteristics of discontinuities: joints, fractures, faults, bedding planes, lithophysae, anisotropy in rock fabric, and so on

- time-dependent properties, if any, under repository-induced conditions

- rock-structure interaction for borehole liners, equipment positioning systems, equipment reaction points, and rock support systems

- ambient rock temperature and gradient.

o Construction and Operational Data

- water control/infiltration measures and and effectiveness, including control of effluents, such as from decontamination

- ventilation effectiveness, resistances, heat removal characteristics, filtering, variations in networks, bulkhead construction and relocation, need for additional shafts/drifts

- blasting damage and disturbed zone characteristics, which will produce irregularities in excavated surfaces relative to borehole closures, shielding closures, positioning of equipment, cutting of rock, etc., and which will affect ground control

- dust production and control

- vibration control and effect on rock, supports, liners, and waste packages

- ground support effectiveness and longevity under repository-induced conditions

- procedures for re-excavation, if applicable, and for blind location of waste packages

- incidence of unexpected ground conditions and provisions for same

- waste handling, transportation, and disposal methods, both for containerized and unpackaged waste materials; rate, efficiency, reliability

- operational analysis to determine responsiveness to off-normal conditions or unanticipated events given subsurface access, ventilation, and space limitations

- processes or events in between the time of emplacement and retrieval

- inspection procedures for waste packages, bulkheaded drifts, and emplacement boreholes given likely ranges of conditions in the subsurface

- acquisition and storage of emplacement records

- monitoring of air and fluids prior to, during, and following retrieval

- utilization of equipment: maintenance, training, human factors suitability of equipment to retrieval environment, alignment at emplacement site

- redundancies in operating, support, instrumentatation, monitoring, ventilation, and other systems

- removal and handling of overcoring cuttings, excavated muck, and so on.

- handling of individual waste packages that are at very high skin tempatures

o ~~Unanticipated processes and events~~

o Waste package design in view of retrieval loadings and geochemical environment

Site characterization data must encompass the combinations of these parameters that would be experienced in retrieval. It is seen that ther are information needs that combine and extend basic site characteristics in ways widespread elevated temperature conditions, efficiency in removing heat from extensive regions of repository workings through ventilation, impact of vibrations and pulling forces on waste package integrity, and many others. These combinations will govern the expectation of retrieval success, but may not be completely

struck

covered in the site characterization program. These considerations and their synergistic effects constitute a need for separate demonstrations and analyses, to which site characterization data collected for other reasons may contribute.

4.4.3 Required Demonstrations of Systems and Components

Retrieval systems and components will need to function within the range of conditions prevailing at the time of retrieval. While site characterization data will help define those conditions, the effectiveness of retrieval operations cannot be assured unless the performance of the retrieval systems and components is assured. Therefore, the function of these systems and components must be studied through demonstrations that are relevant to actual retrieval conditions.

Since retrieval constitutes a contingency that may never be used, but that is critical nonetheless to the assurance of full control of the waste until decommissioning and closure, a conflict arises when approaching the problem of how to demonstrate retrievability. On the one hand, complete knowledge of the retrieval system and its performance under realistic conditions would seem to be required. However, this would require also that the technology of retrieval be fully-developed and proven, covering the full range of repository conditions and encompassing human factors, such as training and oeprator skill. On the other hand, it can be argued that such a level of design is an unnecessary and even detrimental burden on the designers, since the range of potential retrieval scenarios is large and, moreover, allocation of design resources to solving such a range of hypothetical problems could detract from the efforts to design repository systems that are expected to be necessary. Furthermore, such a level of assurance may not even be possible for a new technology such as retrieval. It will therefore be necessary to judge whether "reasonable assurance" of full retrievability has been attained in the design, but it would not be advisable to require full proof of retrievability in every conceivable case.

If components or operations whose failure could preclude retrievability have attributes that are not covered by the construction experience or site data that would be expected to grow out of the site characterization program, then the NRC would require a demonstration sufficient to evaluate the reliabilities of such components or operations, within the context of "reasonable assurance".

In particular, demonstrations of retrieval equipment would most likely be required for items that incorporate new technology or combinations of technology that have not been proven through field use for similar applications. Examples of equipment falling into this category would be the retrieval systems and components used to extract waste packages from boreholes.

Another category would incorporate items of equipment or processes where prior applications exist, but are changed significantly for the intended retrievability concept. An example of this type of equipment would be the systems and components for retrieval of waste when off-normal conditions exist.

4.4.4 Types of Demonstrations Proposed by the DOE

Three types of demonstrations are outlined in SAND 84-2242, entitled "NNWSI Project Retrievability: Strategy for Compliance Demonstration". They are:

1) Proof-of-Concept Demonstrations

2) Prototype Demonstrations

3) In-Situ Demonstrations

Proof-of-Concept Demonstrations

SAND 84-2242 indicates that Proof-of-Concepts demonstrations will not be required for the vertical emplacement configuration because a demonstration was performed in granite at the Climax facility, NTS. These tests for the most part were used to determine that feasibility of excavation and vertical boring, and include coring up to 152 mm ("6") diameter holes, but do not include overcoring to retrieve a cask with a diameter of approximately one meter. Should this configuration be chosen, Proof-of-Concept demonstrations for overcoring may be required.

According to SAND 84-2242, Proof-of-Concepts demonstrations for the horizontal emplacement configuration would include:

1) Borehole Drilling

2) Borehole Components

3) Turntable and Emplacement Mechanism

4) Retrieval Backup System

After these Proof-of-Concept demonstrations, a decision as to which is the preferred configuration (horizontal or vertical) would be made and then prototype demonstrations would be done for the selected configuration.

This could be a very costly and time-consuming approach. The choice between vertical and horizontal emplacement should be evaluated in detail and potential risks carefully compared so that there is justification for the expense and time involved with Proof-of-Concept demonstrations of horizontal emplacement if this approach is to be used.

It is our opinion that the Proof-of-Concept demonstrations for the horizontal configuration are necessary, but only if the benefits that would be derived from horizontal emplacement can justify the cost and performance risks involved. For vertical emplacement the most important Proof-of-Concept demonstration would probably be for the overcoring and container withdrawal procedures under off-normal conditions.

A satisfactory scale for these types of demonstrations may be difficult to determine, especially in demonstrations associated with borehole equipment and fittings, due to the fact that the actual size of the boreholes is small in relation to drift size and operating or development equipment sizes. The scale of the models should be sufficient to allow a fairly detailed and realistic demonstration to be conducted, particularly with respect to waste container size, weight, and temperature.

It would be expected that site characterization data would be sufficient to meet most of the Proof-of-Concepts requirements for remining, ground support performance, rock mass disturbance, and ventilation, so long as separate models and analyses dedicated to retrievability are performed. Site characterization results may not directly cover all geologic conditions, however. Prototype Demonstrations

Whichever configuration is selected will require full-scale, fully-operational demonstrations. As stated in SAND 84-2242, the demonstrations would include:

1) Borehole drilling

2) Borehole preparation

3) Waste emplacement

4) Waste retrieval

It is our opinion that the waste retrieval demonstration should include simulated "off-normal" conditions and should be conducted in an underground environment under simulated repository conditions. With the number of boreholes to be placed in the repository, off-normal conditions should be anticipated. It will be necessary to show that a viable method of retrieval does exist for such conditons no matter how unlikely their occurrence may be. Site characterization data and operational analyses should be presented in support of the ranges of conditions covered by prototype demonstrations.

In-Situ Demonstrations*

The DOE proposes to establish a training area for retrieval and emplacement operations and recommends that representative boreholes within the repository be selected for performance confirmation purposes -- all boreholes so chosen would be fully instrumented. Because this implies that waste emplacement would previously have been allowed, this is a suitable intention, only so long as prototype demonstrations have previously accomplished in the rock mass of interest, with repository-induced conditions, consideration of post-retrieval performance incorporated and results available to support licensing.

Instrumentation is not detailed in SAND 84-2242 and will be discussed below.

Demonstrations and Site Characterization

Data on rock properties and construction experience acquired during site characterization will have to be a prime consideration for Proof-of-Concept and prototype demonstrations. The demonstrations should reflect the latest data acquired during site characterization and thus the actual repository conditions as can best be determined or modeled at the time of the demonstration.

It is our opinion that Proof-of-Concepts and prototype demonstrations should be a part of the site characterization activities for the following reasons:

1) Should a particular piece of equipment or system not perform well during the demonstrations, adjustments and/or other options can be developed prior to a final licensing decision, without major delays in the repository licensing process.

2) Licensing cannot proceed without positive assurance that retrieval is not precluded.

3) Time is a primary concern. Building equipment, gathering data, demonstrating equipment and assessing demonstrations will require a good deal of time.

4) Should unexpected site conditions be encountered during construction, adjustments to retrieval systems can be made accordingly.

5) Instrumentation programs, for performance confirmation programs in which retrieval would occur, can be developed during prototype demonstrations so that the in situ testing/instrumentation will be well developed during the site characterization phase and adjusted as needed for the performance confirmation demonstrations.

Instrumentation, Testing and Quality Control for Retrieval Demonstrations

Because retrieval equipment will be used in an extremely harsh environment, ~~it~~ should be demonstrated and proven in an environment that resembles the actual or anticipated environment as closely as possible.

Major factors to be considered are:

1) High temperature/thermal expansions

2) Squeezing and possible linear deformation or failure

3) Isolation and monitoring for radioactive contamination -- solids, gas, and fluids

4) Ventilation and cooling efficiencies/time

5) Emplacement Drift stability and size limitations

6) Tolerances required for boreholes

7) Size and weight of waste packages to be handled

These factors will require consideration for normal and off-normal conditions to assure the retrievability of waste packages.

4.6 ~~4.5~~ LEVEL OF RETRIEVAL DEMONSTRATION NEEDED DURING SITE CHARACTERIZATION

Previous discussion in this paper has shown ~~why~~ that retrieval should be afforded the same level of design and assurance as any other feature of the repository providing public or worker safety assurances. The aim of demonstrations should be ~~to fulfill~~ operational analyses and design studies that are not fully-supported by general site characterization data or ESF operating experience. While these assurances, and therefore the data and demonstrations they rest upon, are needed before license issuance and in many cases before, construction authorization, it is not necessary for retrieval designs and demonstrations to outpace the repository design. However, data and demonstrations sufficient to support retrievability should not lag behind the design of repository systems such that retrieval system provisions could become "appendages" to repository systems, such as ventilation, muck handling, waste handling, monitoring and so on.

Ultimately, physical demonstrations of integrated retrieval systems, under realistic ranges of conditions, will be needed to assure the ~~waste will be under sufficient control to~~ and justify a license to receive and process waste.

Up to that point, the function of integrated systems could be simulated from demonstrations of their principal subsystem components, so long as these components are also studied under realistic conditions. The level of simulation involved should diminish as the pre-license process advances. These "proofs-of-principle" (or Proofs-of-Concept, in current DOE nomenclature) must reflect a rational identification of the subsystems to be proven and show, through careful experimental design and repository systems analysis, how the subsystem studies taken together are representative of the performance of the retrieval system under realistic, repository-induced conditions.

The preceding chapter identified categories of information needs that should be satisfied, at one time or another, before it can be shown that the proposed retrievability provisions will in fact acceptably assure control of the waste. These can be divided into categories reflecting the degree to which they are site-specific or site-independent, and further, as to the nature of their impacts on repository design, as follows.

- Aspects that are site-specific and depend on gross rock mass properties could affect the basic repository layout and other design features that would be difficult or impossible to modify at the time of retrieval. Demonstrations to support these aspects would need to be essentially complete, and the principles essentially proven, prior to issuance of construction authorization. Examples are ventilation effectiveness (need to leave space for additional shafts and drifts), or performance of rock support in heated drifts (may determine excavation limits). Most of the basic thermomechanical rock mass behavior tests and design/operations studies, such as detailed ventilation sequencing, fall into this category.

- Aspects that are site-specific, but do not affect comprehensive features of the repository initial construction, need to be supported by site characterization data, but some of these data could accrue from, or be collected during, repository construction. Examples are: a widening of the range of rock conditions studied in borehole liner-rock iteration analyses, tests of the thermomechanical response of rock adjacent to faults or fractured zones during positioning of equipment and overcoring operations, strengthening of the concepts of ranges in repository conditions throughout the repository block, and initial tests of prototype equipment and systems for inspections, and for locating and extracting waste containers.

- Non-site-specific studies and tests that must be performed to support proofs-of-principle and prototype development may be performed off-site initially in mock-ups, but must eventually be proven in underground environments of equivalent harshness to that expected in a repository at the time of retrieval. Examples are performance of radiological monitoring and hydraulic actuating systems in hot, dusty environments; performance of overcoring and liner cutting equipment; development of maintenance, repair, and decon procedures covering a very large number of individual container retrieval cycles. Most of the very basic design parameters for these studies are already known or will be generated by site characterization activities, such as rock hardness, drillability, dust generation, and so on. However, there may be data, particularly in terms of heat release and effects of heat on porosity/ saturation, that are important to fundamental design concept development and may not be sufficiently covered in general site characterization activities unless they are identified in advance and factored into the site characterization plan. The concept development and system design of equipment that is non-site-specific or not highly site-dependent could be begun off-site and be contemporaneous with site characterization, to the extent that satisfaction of data needs allows.

Sufficiently-comprehensive proofs-of-principle and prototype testing would be adequate for authorization of construction. In situ demonstrations and tests of fully-integrated retrieval systems should be performed to support license issuance.

The repository design process should accommodate updates based on retrievability needs just as it would accommodate updates for any other design features. Interface controls, design change reviews, and technical developments used in the design process should incorporate retrievability criteria in a useful and enforceable way.

Retrievability depends in large part on site-specific environmental and rock behavior factors. The ability of the design to effect the needed rock behavior and environmental conditions under which the proposed retrieval system would operate, is a design parameter in itself. For example, the reliable operating range of each piece of retrieval equipment with respect to drift temperature and accumulated rock fall should be defined. This sets a performance requirement for both the ventilation and rock support systems with respect to retrievability. It is therefore incumbent on the designers to assure, through analyses and demonstrations, that the ventilation system will achieve the design goals and that the design-goal, rock-mass behavior (which may depend in part on temperature and therefore ventilation) will be achieved, for a range of retrieval scenarios.

Performance factors that could give rise to retrieval, and performance indices governing retrieval (continued maintenance of containment, isolation, and retrievability as appropriate during and following retrieval) need to be encompassed by demonstrations. These will be partially, and in some cases entirely, site-specific. Performance expectations of the retrieval system may govern concept development: certain conceptual approaches to waste location and removal may be technically feasible for those purposes, but may pose such a threat to repository performance that it is unsuitable for detailed design.

Demonstrations and proof-of-principle must be able to accommodate a retrieval decision; that is, the risks and benefits of retrieval or non-retrieval should be assessable before retrieval takes place. This impacts both the breadth and reliabilities of the demonstrations planned. Risks of leaving the waste in place should be assessable from the performance confirmation program. Risks of retrieval should be predictable from retrieval-specific demonstrations, as to the reliability of the retrieval system (ability to consistently achieve the design goals), and as to the performance goals claimed for the retrieval system. This will require a high level of operational analysis for a broad scope of retrieval scenarios to adequately document the reliability of the proposed system.

Tests to demonstrate both effects on performance measures and the reliability of the retrieval system will require proofs of different sets of principles initially. Retrieval should be incorporated into repository performance analyses for the waste package, worker and public preclosure safety, and post-closure impact. Failure analyses should be performed conservatively to provide initial reliability estimates because the reliability of an integrated system may be much less than the reliabilities of its component parts. Prototype and in situ demonstrations must then be developed to check the results of these proof-of-principle.

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APPENDIX A: GLOSSARY

"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.

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

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

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

"Permenant 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.

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

APPENDIX B

10 CFR 60, Statements of Consideration (10 CFR 60, SC, p. 10)

Retrievability

The purpose of this requirement was to implement in a practical manner the licensing procedures which provided for temporal separation of the emplacement decision from the permanent closure decision. Since the period of emplacement would be lengthy and since the knowledge of expected repository performance could be substantially increased through a carefully planned program of testing, the Commission wished to base its decision to permanently close on such information. The only way it could envision this was to insist that ability to retrieve -- retrievability -- be incorporated into the design of the geologic repository.

The proposed rule would have required in effect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years (30 years for emplacement, 50 years to confirm performance, 30 years to retrieve). The Commission solicited comment, noting that it would not want to approve construction of a design that would unnecssarily foreclose options for future decision makers, but that it was concerned that retrievability requirements not unnecessarily complicate or dominate repository design.

While the benefits of retaining the option of retrieval were recognized, the length of the proposed requirement, in the opinion of several commenters, was excessive. In their view, the Commission had given inadequate consideration to the additional costs of design, construction, and operations implied in the original proposal; however, no new cost or design information was presented by the commenters.

The Commission adheres to its original position that retrievability is an important design consideration. However, in response to the concerns expressed, the Commission has decided to rephrase the requirement in functional terms. The final rule this specifies that the design shall keep open the option of waste retrieval throughout the period during which the wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. By that time, significant uncertainties will have been resolved, thereby providing greater assurance that the performance objective will be met. In particular, the performance confirmation program can provide indications whether engineered barriers are performing as predicted and whether the geologic and hydrologic response to excavation and waste emplacement is consistent with the models and tests used in the Commission's earlier evaluations. While the commission has provisionally specified that the design should allow retrieval to be undertaken at any time within 50 years after commencement of emplacement operations, this feature is explicitly subject to modification in the light of the planned emplacement schedule and confirmation program for the particular geologic repository.

Some commenters suggested that the technical criteria specify the conditons that would require retrieval operations to be initiated. Such provisions would not belong in Subpart E, which is concerned with siting and design. Nor are they needed elsewhere. In the Commission's view, it is clear that retrieval could be required at any time after emplacement and prior to permanent closure if the Commission no longer had reasonable assurance that the overall system performance objective would be met. This situation coudl exist for a variety of reasons and the Commission believes that it should retain the flexibility to take into account all relevant factors and that it would be imprudent ot limit the Commission's discretion by specifying in advance the particular circumstances that would make necessary to retrieve wastes. It should be noted that DOE may elect to maintain a retrievability capability for a longer period that the Commission had specified, so as to facilitate recovery of the economically valuable contents of the emplaced materials (especially spent fuel). So long as the other provisions of the rule are satisfied this would not be prohibited. This consideration, however, plays no role in the Commission's requirement pertaining to retrievability. The Commission's purpose is to protect public health and safety in the event the site or design proves unsuitable. The provision is not intended to facilitate recovery for resource value.

The Commission has also included a specific provision clarifying its prior intention that the retrievability design features do not preclude decisions allowing earlier backfilling or permanent closure. A related clarifying change has been the incorporation of a definition of "retrieval." This definition indicates that the requirement of retrievability does not imply ready or easy access to emplaced wastes at all times prior to permanent closure. Rather, the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation. The idea is that it should not be made impossible or impractical to retrieve the wastes if such retrieval turns out to be necessary to protect the public health and safety. DOE may elect to backfill parts of the repository with the intent that the waste emplaced there will never again be disturbed; this is acceptable so long as the waste retrieval option is preserved.

The Commission has thus retained the essential elements of the retrievability design feature, but has provided greater flexibility in its application. The Commission recognizes that retrievability implies additional costs-- more, perhaps, for some media and designs than for others--yet it believes this is an acceptable and necessary price to pay if it enables the Commission to determine with reasonable assurance, prior to an irrevocable act of closure, that the EPA standard will be satisfied.