Department of Energy
Washington, D.C. 20585

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Washington, D.C. 20555

Subject: DOE Review of the NRC Draft Generic Technical Position On In Situ Testing During Site Characterization for High-Level Nuclear Waste Repositories

Dear Mr. Miller:

Enclosed is the DOE response to the NRC Draft Generic Technical Position (GTP) on In Situ Testing. These comments reflect the benefit and insights gained from earlier meetings with the NRC technical staff.

Basically we believe that the subject GTP provides helpful guidance to our current efforts to develop a comprehensive test program. However, we also believe that the GTP should not be released in final form without certain modifications and improvements that are suggested in the enclosed review.

In addition to underground testing for site characterization leading to a license application, the GTP covers various exploratory tests, such as geophysical logging, that DOE has already performed on potential host rocks at the Federal sites. DOE expects to include some of these tests and their results in a future license application, assuming of course, that these activities can be shown to have been conducted under acceptable procedures and controls.

The GTP specifies various tests, such as emplacement/retrieval tests, that DOE currently plans to initiate during the phases that follow site characterization. The DOE plans to continue testing beyond the site characterization phase. Thus, some of the tests that the GTP identifies as site characterization tests, DOE intends to perform as confirmatory or operational tests.

We hope you will find the enclosed detailed comments to be of help in your preparation of the final revision of the GTP. The DOE looks forward to continuing its interaction with the NRC staff in resolving the technical issues associated with in situ testing and would be pleased to meet with you to discuss our comments.

Sincerely,

Ralph Stein

Ralph Stein
Acting Director
Geosciences and Technology
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Office of Civilian Radioactive
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Enclosure

REVIEW: NRC DRAFT GENERIC TECHNICAL POSITION ON IN SITU TESTING DURING SITE CHARACTERIZATION FOR HIGH-LEVEL NUCLEAR WASTE REPOSITORIES

March 28, 1985

INTRODUCTION

The "Draft Generic Technical Position (GTP) on In Situ Testing During Site Characterization for High-Level Waste Repositories," released by the engineering branch of NRC, describes the in situ testing activities that DOE will have to cover as part of its program for site characterization prior to submitting a license application.

GENERAL COMMENTS

1. The GTP is not consistent in its usage of the term in situ testing. For example, on page 5 "limited subsurface lateral excavations and borings" are clearly distinguished from "in situ testing at depth" in the definition of site characterization. In the next paragraph on page 5, and elsewhere in the text, NRC defines in situ testing as any underground testing (including subsurface excavations and borings) "for site characterization purposes." DOE prefers the use of the term "underground testing" in this paper in order to avoid any confusion on terminology.

   DOE does not see any justification, however, to limit the definition of in situ testing to only the time period corresponding to site characterization, especially since the GTP correctly points out that some underground testing will continue beyond site characterization.

2. The GTP appears to overemphasize interactive (coupled) testing, particularly since no technical justification for the need, or scope of such testing is included (see page 14). No examples are given of the interactive (coupled) effects tests that NRC has requested repeatedly in the past. Additional guidance on interactive (coupled) tests is desirable.

3. The NRC has chosen to address only the underground testing portion of site characterization in this GTP. While DOE agrees that surface based testing must be carefully controlled to maintain site integrity, the potential for use of surface-based tests should not be understated, such as on page 10 where the statement is made that lateral extent and thickness of the repository host rock can <u>only</u> be made by in situ testing. This statement is incorrect and not in agreement with the terminology "in situ testing at depth" employed on page 5. Some of the specific tests mentioned in Section 3.2.1 could be performed as part of surface based exploration activities.

4. The NRC should indicate whether the listing of tests in the "General Description of In Situ Testing" section is a required minimum applicable to every site or simply a recommended listing with desirable examples. The NRC should clearly point out what portions of the GTP are the requirements mentioned in the third paragraph on page 6 and what portions are the recommendations.

5. The planned GTP on Performance Confirmation Tests mentioned on page 6 should be released as soon as possible in order to provide adequate and timely guidance to the DOE.

6. NRC, in Section 4.1 ("Rationale for Testing"), states that the in situ test plan "should identify (a) all issues...; (b) the information needs that must be satisfied...; and (c) the tests and their procedures..." This statement reflects two apparent assumptions that all issues will be identified prior to commencement of detailed characterization and testing, and that it will be possible for DOE prior to the start of site characterization, to provide detailed test plans for the latter phases of detailed characterization. While it is believed that all relevant issues will be identified, it should be recognized that new issues may arise during characterization. Accordingly, it is strongly recommended that the NRC staff insert qualifying statements, as appropriate, to reflect the anticipated evolution of underground testing activities as the program advances.

7. DOE recommends that NRC provide additional guidance on acceptable testing standards.

SPECIFIC COMMENTS

Section 1.0, Paragraph 3

Revise the statement "... 1) to obtain data which will assess..." to read "to obtain data for use in assessment of the suitability..."

Section 2.1, Paragraph 2

Subsections (B) and (C) of the NWPA Section 114(a) are incorrectly referenced. The correct citation would be Section 114(a)(1). The NRC cites Subsections (B) and (C) as a justification for in situ testing. These sections mention site characterization activities, but do not specify at-depth analysis. Section 114(A)(1)(E) does specify "at-depth site characterization analysis" and may provide a more appropriate reference.

Section 3.0, Paragraph 1 and Figure 2

The maximum uncertainty precedes the various types of testing performed to select sites for characterization. Considerable uncertainty has already been removed, as documented in the draft EA's. NRC's expectation as to the amount of uncertainty reduction during underground testing alone is over-simplified and optimistic. Other site characterization activities and follow-on testing programs will be required to further reduce this uncertainty and ensure the representativeness of the initial testing to the entire repository.

Sections 3.1, Paragraph 1; 3.2.1, Part F; 4.5, Paragraph 1; 4.8, Paragraph 1; and 5.0, Paragraph 1

The expression "coupled thermal-hydrological-mechanical-chemical effects" is used repeatedly in this document. The term "coupled" is first used by NRC in the Draft Site Characterization Analysis (NUREG-0960), Volume 1 (DSCA) to describe the combined effect of in situ stress, excavation-induced stress, and heat-induced stress. DOE recommends the use of term "interactive" from 10 CFR 60 instead of the term "coupled."

Section 3.1, Paragraph 2, Item 4

Estimating the lateral extent and thickness of the host rock from within the repository horizon would be very costly, time consuming, and not conclusive until the principal drifting of the entire repository was actually completed. The term "many boreholes" is subject to considerable interpretation. It seems entirely possible that more boreholes could be drilled from the surface at each site before the restriction of 10 CFR 60.10(d)(2) is violated.

Section 3.2, Paragraph 1, Item 6

The lateral extent and host rock variability can also be assessed by the surface drilling and testing program. The term "sufficient extent" must be defined with more clarity. Sufficient extent might be difficult to demonstrate from a reasonably sized ES test facility alone. DOE suggests that the phrase "and core drilling" be changed to "and/or core drilling" to allow operational flexibility. Allowance should be made for alternative methods which may be equally acceptable, and more achievable technically, as the lateral distance from the repository site increases.

Section 3.2, Paragraph 1, Item 8

DOE suggests rewriting this sentence as follows: "Hydrological, geochemical, geomechanical, and thermal-hydrological-mechanical-chemical testing..."

Section 3.2.1, Parts A through F

The number and scope of underground testing activities requested during site characterization are greater than currently planned by DOE. In addition to test varieties DOE would employ during the site characterization phase, NRC lists varieties in the GTP which are more appropriately performed as part of underground exploration (which can occur prior to the site characterization phase) and as part of operational testing (after the site characterization phase).

Section 3.2.1, Paragraph 1.

In the "General Description of In Situ Testing" section, the following sentence appears: "As a minimum, geological, hydrological, geochemical, geomechanical, and coupled thermal-mechanical-hydrogeological-geochemical tests described below (emphasis added) should be considered in formulating the in situ test plan." The subsequent Part F on Coupled/Interaction Tests does not provide examples of the needed tests.

Section 3.2.1, Part A.

In normal mining practice, the majority of the boreholes in Item A(2) would be horizontal or inclined. Many of the geophysical tests mentioned would be difficult to perform in nonvertical holes and would require highly specialized equipment. Mention of directional surveying in the exploratory boreholes is omitted, but should be included in the drilling activities. Some of the logs requested in Item A(4) (such as gravity and magnetics) are best employed to detect very large scale features and should yield little useful information if applied on the smaller scale of interest implied by the discussion. The word gamma is misspelled in Item A(4).

Section 3.2.1, Parts B, C, and D.

Seals are of major concern in the Design/Rock Mechanics section of the NRC Issue-Oriented Site Technical Position (ISTP's), but this listing of tests omits mention of hydrological, geomechanical, and geochemical testing of seals. Will underground tests of seals be classified by NRC as activities occurring in site characterization or performance confirmation testing?

Section 3.2.1, Part B.

The behavior of the hydrological system over time is crucial to the overall acceptability of a candidate volume of rock. Determining time dependent behavior seems inadequately addressed in the hydrology section. Pre-excavation testing using boreholes will be necessary to determine the ground-water conditions that shafts and drifts might disturb. Changes in the ground-water conditions resulting from excavation will have to be determined.

Sections 3.2.1, Part C, Item 1 and 3.2.1, Part E

The confidence that the NRC is placing in the block test to effectively provide the information necessary to assess rock mass characteristics is based upon the theoretical assumptions that a "representative volume" would have a cross-section smaller than that of a drift and that the variability within the host rock would be sufficiently low to require only a limited number of tests. The range of joint frequency, orientation, persistance, roughness, alteration and wetness (among other pertinent characteristics) will govern whether this test could yield information sufficient to meet NRC expectations. There are other tests, such as pillar tests, which could provide comparable information.

Section 3.2.1, Parts C and D.

A large proportion of the Design/Rock Mechanics issues raised in the NRC ISTP's concern the performance of the backfill component of the engineered barrier system. However, only one test in this GTP, the mine-by test to observe backfill response, makes direct mention of backfill. DOE believes geochemical tests, interactive (coupled) effects tests and retrievability tests will also employ backfill. Will underground tests of backfill be classified by NRC as activities occurring in site characterization or performance confirmation testing?

Section 3.2.1, Part D.

The majority of tests listed in the geochemistry section will be performed in a laboratory to ensure accurate results. The underground part of these tests will be limited to the scientific sampling of the underground openings. The GTP should reflect this distinction.

In Item 3, drop the word "chemical" and add the word "petrology" after the word "mineralogy." A chemical analysis alone will not provide adequate information about mineralogical content.

Item 6 lists "dual tracer tests." NRC should identify what is meant by the term "dual," since a dual tracer test could refer to radioactive and nonradioactive tracers, sorbing and nonsorbing tracers, or other possible combinations. DOE expects to be able to employ tracers in its hydrological testing in addition to using them in geochemical testing.

Section 4.1, Paragraph 2

DOE cannot agree to incorporate references to all test procedures in its test plan, because some tests will require modification for site specific conditions. Further, it is not likely that the details of all necessary procedures will be identified at the time the test plan is prepared. The development of a successful test program is an evolving process. In general, it may not be possible to complete the details of the procedures until the characteristics of equipment, orientation, location, and rock conditions are adequately known.

Section 4.7, Paragraph 2.

The NRC should expand the concept presented in the last sentence that an independent peer review can determine when adequate confidence has been established. This statement raises questions such as whether the NRC will accept such a decision, what level of confidence the NRC will require, what composition the group should have to be acceptable to NRC, and what is meant by "independent."

Section 4.10, Paragraph 1.

The first bullet mentions "quality." Is "quality" in this usage meant to stand for acceptable quality assurance?

Summary.

The summary lists ten items that the in situ test plan must (emphasis added) include. The DOE interprets this statement as a recommendation rather than a requirement, because it is DOE's understanding that technical positions (such as this GTP) are issued as guidance documents and as such do not establish regulatory requirements. Also, DOE would recommend that the underground test schedule and durations be compared to the program schedule since it includes more detail than (while still incorporating) the Congressionally-mandated schedule for site selection and licensing.

Figure 1

This figure appears to indicate that excavation of drifts and emplacement rooms will be completed at the time the license to receive and possess is issued. This is not necessarily the case and the figure should be revised accordingly.

108.9/NST/84/08/06/0

U. S. NUCLEAR REGULATORY COMMISSION

DRAFT GENERIC TECHNICAL POSITION ON IN SITU TESTING DURING SITE CHARACTERIZATION FOR HIGH-LEVEL NUCLEAR WASTE REPOSITORIES

ENGINEERING BRANCH

September 1984

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GENERIC TECHNICAL POSITION ON IN SITU TESTING DURING SITE CHARACTERIZATION

1.0. INTRODUCTION

Prior to submittal of a license application, the Department of Energy (DOE) is required by the Nuclear Waste Policy Act of 1982 and by 10 CFR Part 60 to conduct a program of site characterization. The Nuclear Regulatory Commission (NRC) defines site characterization in 10 CFR 60.2 as "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 characterization should be undertaken."

"In situ testing" as discussed in this generic technical position (GTP) refers to the conduct of underground tests for site characterization purposes. Examples of the types of in situ tests are, geological, geophysical, hydrological, geomechanical, thermal, or geochemical tests. These tests are to be performed from the exploratory shaft(s) and underground openings on the host rock and other materials and components such as representative waste package, engineered backfill, linings, seals and other support structures. The conditions under which these in situ tests are to be run, must represent, as closely as possible, realistic repository environment (for example temperature, stresses, ...etc). In situ testing, then, constitutes one important element of site characterization.

The objectives of in situ tests are: 1) to obtain data ~~which will~~ assess the suitability of a particular site and a particular geologic medium to host high-level nuclear waste, and 2) to provide realistic and representative input parameters for the design of a geologic repository and analysis of its performance.

Because of the long time span (10,000 years) during which the repository must function to isolate the waste, and the deficiency in understanding the effects of heat on rock and mineral behavior, as well as the induced hydrological and geochemical changes, the in situ tests take on special significance. The in situ tests can only be conducted for a limited duration in comparison to the total repository life. Therefore, prediction of future repository performance will have to be made by certain analytical models. Models have their own

limitations and are sensitive to the quality of data used as input parameters. Uncertainties in the prediction process can be minimized by conducting appropriate in situ tests on representative volumes of rock, and employing appropriate models to account for possible spatial variation of engineering properties within the rock formation.

This GTP is intended to provide guidance to DOE on what NRC considers to be the essential elements of an in situ test program to address the requirements and performance objectives of 10 CFR Part 60 with respect to a site to be described in a license application.

As defined above, this GTP covers in situ testing during the site characterization period at the end of which an application is made for a license, followed by construction authorization, construction, the issuance of a license to receive and possess waste, and eventual closure. The progression of site activities and its relationship to milestones are illustrated in Figure 1. It should be noted that in situ testing and site characterization will take place at three sites, before DOE submits a license application for one site. Many of the requirements described in this GTP are for tests that can be of long duration, and therefore are likely to continue to provide valuable information beyond the site characterization period. To supplement the data from continuing in situ tests, additional tests (perhaps more refined by the knowledge gained from the earlier tests) must be conducted to assess the performance of the repository. Such tests are among those referred to in 10 CFR 60 Subpart F as "Performance Confirmation Tests" and a technical position on such tests will be described in a subsequent GTP.

This GTP is organized in the following manner: Section 2.0 covers the in situ testing requirements as stated in the Nuclear Waste Policy Act of 1982 and the NRC 10 CFR 60. Section 3.0 describes NRC's technical position on in situ testing and identifies in general terms geological-geophysical, hydrological, geomechanical, and geochemical tests. In Section 4.0, detailed discussions are provided on the extent and duration of in situ testing, sufficiency criteria, presentation of test data, and other aspects of an acceptable in situ testing program.

2.0. PUBLIC LAW AND REGULATORY FRAMEWORK

The requirement of conducting in situ tests has been established by the Nuclear Waste Policy Act of 1982 and the NRC Rule 10 CFR 60. In this section these requirements are outlined. The intent of the Act and the NRC rule is that the in situ testing program should: (1) obtain data to assess the suitability of a particular site; (2) provide representative parameters for design of a

repository; (3) help resolve important issues which affect the repository performance, prior to the licensing hearing.

2.1. Nuclear Waste Policy Act of 1982 (NWPA)

Public Law 97-425 (Nuclear Waste Policy Act of 1982) Section 113(b) 1(A)ii requires DOE to submit a site characterization plan including a description of onsite testing which should cover: (a) the extent of planned excavations for any on site testing with radioactive or nonradioactive materials, and (b) plans for any investigation activities that may affect the capability of such candidate sites to isolate high-level radioactive waste and spent nuclear fuel and plans to control any adverse safety related impacts from such site characterization activities. Section 113(b)1(B) specifies inclusion in this description, to the extent practicable, the relationship between the waste form or packaging and the geologic medium of such site, and Section 113(b)1(C) requires a description of the conceptual design that takes into account likely site specific requirements. In situ testing is required to meet these provisions of the Act.

Subsections (B) and (C) of Section 114(a) require the DOE to submit a statement of the basis of the site recommendation and a discussion of data obtained in site characterization activities relating to the safety of such sites. In situ test data will form a substantial part of the basis for site approval and construction authorization.

2.2. Nuclear Regulatory Commission Rule (10 CFR 60)

The NRC Rule 10 CFR 60 requires in situ testing as a part of site characterization. Therefore, the construction of exploratory shafts, excavation of test facilities and performance of in situ tests will precede the license application. The rule* directs DOE to meet the following requirements:

§60.10 Site Characterization

(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) ...DOE is also required to conduct a program of site characterization including in situ testing at depth, with respect to alternative sites.

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* References are to the rule as currently codified. The Commission has stated its intention to undertake additional rule making to deal with any changes in the licensing Procudures that may be necessary in light of the Nuclear Waste Policy Act - See 48 FR 28195, June 21, 1983.

(d)(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.

§60.11 Site Characterization Plan

(a)(6) The plan shall include a description of the site characterization program including (i) the extent of planned excavation and plans for in situ testing, ... etc.

§60.21 Content of Application

(c)(1)(ii) The Assessment shall contain -
(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.

§60.151 Applicability. [of Subpart G - Quality Assurance]
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.

3.0. TECHNICAL POSITION ON IN SITU TESTING

In situ testing is essential to assess the suitability of a geologic repository site for hosting high-level nuclear waste and to provide realistic input parameters for the repository design. DOE has the responsibility to establish the representativeness of the limited volume of rock subject to in situ testing with respect to the repository block volume. The data from surface borehole testing and laboratory testing on small scale samples should be integrated with the in situ test results for successful site characterization. Therefore, in advancing this generic technical position, the NRC staff states that necessary and sufficient amount of in situ testing should

be performed at depth on the host rock, under an adequate quality assurance program prior to license application, to support, if the facts so warrant, a staff position that the requirements for issuance of a construction authorization (§ 60.31) have been met. The in situ testing should significantly contribute to reducing uncertainties about the suitability of the host rock to provide long-term isolation and containment of the high-level nuclear waste. As shown in Figure 2 the uncertainty about compliance with 10 CFR 60 performance requirements is maximum prior to the exploratory shaft construction and is expected to decrease significantly during the site characterization period. It should be noted that the efforts to lessen the uncertainties will continue even after the License Application.

An in situ testing program should consist of the following two major components: (1) observation of host rock characteristics and measurement of its properties prior to construction and waste emplacement (for example, in situ hydraulic head, permeability, in situ stress and ambient temperature fields, in situ geochemical characteristics, distribution of discontinuities, thermal conductivity, and geologic structure etc.); (2) determination of response characteristics of the host rock and engineered components to construction and waste emplacement (for example, response to thermally, mechanically or hydraulically induced stresses).

It is important to note that in situ testing is one important and necessary element of site characterization. However, in spite of being the most effective and direct approach to host rock characterization, in situ testing has limitations. For example, the lateral extent of underground excavation for in situ testing purposes will be very limited in comparison to the total volume of rock being characterized. The number and duration of tests will also be limited by practical considerations. However, in the absence of in situ test results confidence in the predictions based on borehole and laboratory testing alone will be extremely limited. Therefore, it is important to realize that while in situ testing is necessary, it is not sufficient by itself and requires integration with all other testing.

The following subsections elaborate on the generic technical position.

3.1. Unique Features of In Situ Tests

The state of knowledge in the earth sciences shows that in situ testing is necessary to: a) adequately characterize the rock, and b) rationally design the repository. Understanding rock behavior under repository conditions is complicated by coupled thermal-hydrological- mechanical-chemical effects of waste emplacement. The in situ tests, therefore, provide for the best means of direct assessment of host rock characteristics.

The following are unique features that make in situ tests an essential element of site characterization and rational design of the repository.

1. Size Effects can be Minimized: - It has been shown through numerous laboratory and in situ tests that many of the measured rock properties are influenced by the size of the rock specimen tested; for example, compressive strength and permeability. In highly jointed rocks, the dependence could be more pronounced. In situ tests which measure crucial design parameters clearly minimize the size effect as a source of error.

2. The Rock Mass in its Natural Conditions can be Tested: The natural conditions of the rock mass cannot be exactly duplicated in the laboratory. Examples are: a) geologic features such as joints, shear planes, etc.; b) hydrologic conditions such as hydraulic head, pore pressure; c) temperature; and d) the loading conditions such as the in situ stress field. The in situ tests, by definition, encompass the natural rock conditions, and therefore test the rock in its natural state.

3. Coupled Processes can be Directly Observed: Many coupled processes (i.e., thermal, hydrological, mechanical, chemical) are likely to occur in the host rock in which the nuclear waste will be disposed. In situ tests measure representative properties resulting from coupled processes, unlike most small scale laboratory tests. Furthermore, the in situ tests provide for measuring a possible non-linear behavior which is difficult to extrapolate from small scale laboratory experiments.

4. Host Rock Extent can be Estimated: Lateral extent and thickness of the repository host rock must be assessed during site characterization. Since there are restrictions (10 CFR 60.10 (d)(2)) against drilling many boreholes from the surface, the only means to assess the thickness and lateral extent is from within the exploratory shaft excavations at depth.

5. Host Rock Variability can be Evaluated: Variability in joint patterns and spacing, geology, and hydrologic and geochemical changes can only be directly assessed through in situ testing. Estimation of variability and assessment of ability to predict rock behavior in different parts of the repository are necessary for satisfactory design of the repository.

3.2. General Guidance to In situ Testing

The in situ test program must be site-specific to account for local geologic conditions, the characteristics of the predictive models chosen for use at the site, and the key issues found relevant to the performance of the selected repository design. However, there are several features that are common to all in situ test programs. These features are discussed in the following general guidance:

1. Development of an in situ testing program should consist of:

   ° Establishing the information needs for License Application based on performance requirements, and the acceptable level of uncertainties in repository performance prediction;

   ° Assessing the capabilities and limitations of available tests and measurement methods;

   ° Matching the capabilities of available tests to the perceived information needs;

   ° Developing and validating tests, if necessary; and

   ° Conducting the in situ test program under a well-developed quality assurance program.

2. The test program must be developed such that it has little or no adverse effects on long term repository performance;

3. The underground openings used for in situ tests must be of suitable layout and sufficient extent to properly assess host rock variability and to minimize or, if possible, avoid interference among tests.

4. Constructibility must be demonstrated in the proposed repository host rock;

5. Geoengineering input should be provided for retrievability demonstration.

6. Geologic mapping, geophysical testing and core drilling should be of sufficient lateral extent to assess the characteristics of the host rock and the variability of its properties;

7. Representativeness of in situ test location in comparison to the proposed repository location should be assessed; and

8. Hydrological, geomechanical and thermal-mechanical-hydrological testing should be run to the extent needed, to support the performance objectives (see Section 4.9 for details) on a scale sufficient to realistically represent the inhomogeneities and discontinuities of the host rock being tested.

Although laboratory, near surface, borehole and other geophysical testing from the surface are not within the scope of this GTP, it should be noted that in situ testing should be supplemented by and integrated with all other relevant tests.

3.2.1. General Description of In Situ Testing

As a minimum, geological, hydrological, geochemical, geomechanical, and coupled thermal-mechanical-hydrological-geochemical tests described below should be considered in formulating the in situ test plan. The extent of each kind of testing may vary with the individual site, the selected repository design, and the site issues that require resolution by testing. The following is a general description of these in situ tests.

A. Geological-Geophysical:

(1) Examination and geologic mapping of exposed rock in exploratory shafts and accessible underground excavations;

(2) Drilling of horizontal, vertical, or inclined boreholes from within the exploratory shaft(s) and underground excavations for obtaining samples for testing;

(3) Lithological logging of cuttings and cores obtained from boreholes from the shafts and underground excavations; and

(4) Underground geophysical testing (e.g. resistivity, radar) to determine distribution of geological units and discontinuities; and borehole geophysical testing (e.g. sonic, gama and electrical logging, strain meters, vertical seismic profiling (VSP), borehole gravity and magnetics, and shearwave surveys etc.) to assess the properties of units and the distribution of these units and associated discontinuities.

B. Hydrological:

(1) Estimation of the potential for high rates of groundwater influx into the exploratory shaft and underground excavations, this estimation may be obtained by: a) long pilot holes drilled (see

Section 3.2.1, A. (2)) from the exploratory shaft and underground test facility for detecting the presence of zones of anomalously high hydraulic conductivity in close proximity to the in situ test facility and/or the exploratory shafts; b) correlation of fractures mapped along the drifts with observed zones of groundwater influx and their corresponding calculated flow rates; and if needed c) a chamber test for determining groundwater influx potential;

(2) Monitoring of transient changes in formation pressures in the volume of rock close to the underground workings, and evaluation of changes induced by in situ hydrologic and geomechanical tests, subsequent construction activities, and surface-based hydrologic testing; and

(3) Determination of hydrologic parameters of the host rock, such as directional hydraulic conductivity, total and effective porosity, specific storage, pore water pressure, and degree of saturation.

(4) Planned testing to evaluate the potential significance of fracture flow and matrix diffusion on radionuclide transport.

C. Geomechanical:

(1) Representative volume testing (e.g., block tests) to predict the constitutive behavior (strength and deformability) and potential failure mechanisms of the host rock; and

(2) Measurement of the in situ stresses from underground openings to compare with stresses measured from the surface boreholes, and to arrive at a better estimate of the prevailing stress field around the underground openings.

(3) Demonstration of repository construction, emplacement, and retrievability, and observation of full-scale response of underground openings and backfill by simulation (e.g., mine-by test);

D. Geochemical:

(1) Sampling and in situ testing of retardation and migration characteristics of the host rock to support laboratory studies of

all significant geochemical conditions and phenomena so as to provide a reliable data base for modeling studies.

(2) Measurement of physical parameters such as ambient temperature and pressure;

(3) Chemical analyses of rock cores to determine the pre-waste emplacement mineralogy and elemental composition of the host rock and surrounding strata.

(4) Chemical analyses of the groundwater, including element/species compositions, pH, redox conditions, gas components, and organic/colloidal material, to understand possible transport mechanisms;

(5) Mineralogical and petrological analyses to determine mineral phases, morphologies, distributions, textures, etc.; and

(6) Dual tracer tests for the determination of retardation factors and scaling factors for laboratory tests.

E. Thermal: Thermal loading tests (e.g., small-and large-scale heated block tests) to support modeling studies of repository scale temperature effects and to establish, by simulation, canister scale behavior.

F. Coupled/Interaction Tests: These are near field tests designed to simulate the thermal-hydrological-mechanical-geochemical interaction.

3.3. Summary of Technical Position

To sum up the ideas expressed in Section 3.0, the NRC Generic Technical Position on In Situ Testing is that necessary and sufficient testing should be performed to address the key issues before a license application is submitted. A rational, methodical in situ test plan should be developed in advance of the exploratory shaft construction. The in situ test plan should identify the issues that must be resolved by testing, provide a rationale for testing, scuss the types of analyses to be applied to the test data, describe the esting, and delineate, at least by reference, the quality assurance programs under which testing will be conducted. If certain tests that might generally be considered as key tests are not performed or are postponed, reasons for such decisions should be provided and justified.

4.0 DISCUSSION

4.1 Rationale for Testing

Isolation and containment of high-level nuclear waste in a geologic repository are provided by the following two systems: (a) the engineered barrier system and (b) the geologic setting. The NRC has defined the engineered barrier system as the waste package and the underground facility. The overall repository system provides different types of control on the release and migration of radionuclides from the repository to the accessible environment. A generic sketch showing the repository and the accessible environment is depicted in Figure 3.

Repository design and performance assessment require a knowledge of the input parameters many of which must be obtained from laboratory and in situ testing of different scales and duration. The amount of testing depends on the relative importance of the particular parameter being measured and on the significance of the component being designed to the overall performance of the repository. Therefore the type, amount, scale, and duration of testing will be guided by the specific site conditions and the expected performance of the various components of the repository system. A rationale for the testing should, therefore, be developed (by the Department of Energy) before a 'test plan' is developed for a site. The test plan should identify all important parameters, classify them according to their relative importance, and document their potential variability and the effect of that variability on design and performance. The test plan should also identify the measurement techniques and their reliability, and provide references to test procedures, quality control, and quality assurance. In summary, the test plan should identify; (a) all issues requiring resolution by in situ testing, and measurements (b) the information needs that must be satisfied in order to meet the performance criteria and regulatory requirements; and (c) the tests and their procedures, capabilities and limitations.

4.2. Type of Testing

Three categories of tests may be identified: (a) preliminary testing; (b) site characterization testing; and (c) performance confirmation testing. Site characterization and performance confirmation testing can be either of the two components of in situ testing program identified in Section 3.0 Paragraph 2; observation of host rock characteristics prior to construction and waste emplacement and host rock response after waste emplacement (see Section 3.0 for more detail).

(a) Preliminary Testing is basically all initial testing done to select a repository site for characterization. These preliminary tests can be of different scales and at any location. The results from such tests could be used for making certain preliminary assessments about site suitability

and performance of the medium in general. Preliminary testing is outside the scope of this report and only mentioned here for completeness.

(b) Site Characterization Testing includes testing and measurements performed to gather data sufficient to characterize the site. Again, the testing could be of different scales and duration. In situ testing programs falls into this category. Traceability of test data and test procedures is very important because the results from in situ tests will be used to support a license application.

(c) Performance Confirmation Testing may start during site characterization and will continue until permanent closure as required by 10 CFR 60 Subpart F(§60.140,(b), (c)). However it should be noted that some of the performance confirmation tests will be a continuation of the testing started during site characterization as described in (b) above. The data from confirmation tests are crucial to verification of assumed design conditions and the predicted repository behavior. Discussions on performance confirmation tests are not provided in this GTP; these tests will be described in a subsequent GTP by the NRC.

The test plan should clearly identify the tests under the above categories and discuss how the data from different categories of tests will be used in repository design and performance assessment.

4.3. Planning of Testing

A certain level of variability is inevitable when dealing with geologic media, therefore, the planning and design of in situ testing should consider an estimated range of parameters to be measured. The data from actual testing should reduce variability of parameters and provide representative design input. For example, preliminary repository designs could be based on estimated ranges of in situ stresses and permeabilities. However, the actual range of design values of in situ stresses and field permeabilities of rock would be established by performing in situ experiments. Also, the standards for the quality of data to be produced for the in situ tests should be established from an appraisal of the overall design and performance requirements. More detail on general scope and nature of in situ testing can be found in NUREG/CR-3065 and NUREG/CR-2983 (see list of references).

4.4. Scale of Testing

Because of the complexities of designing and constructing an underground repository, testing will have to be performed at different scales. Laboratory testing on small specimens will provide useful information for preliminary

designs and analyses. However, in many cases, large-scale or full-scale testing will be required to yield a realistic and convincing data base (for a comparative scale of the field tests, see Figure 3). The need for large-scale/full-scale testing will have to be established on a site and design-specific basis. The in situ test plan should discuss the scale of testing and its implications on site characterization. Moreover, the development of underground openings should be of sufficient extent to properly assess the variability in the host rock and adjacent strata. One aspect of scale was expressed by the NRC in the supplementary information to the procedural rule 10 CFR 60, that a facility consisting of two exploratory shafts and approximately 1,000 feet of tunnels would be a practical arrangement for conducting tests at depth for site characterization. (see 46 Federal Register 13973, February 25, 1981).

4.5. Duration of Testing

Testing of geologic materials for certain design parameters can be of long duration. However, many design parameters can be obtained by testing over reasonably short time periods. When the processes being observed are slow, or complex interactions are involved, or time effects are important (or predominant), it is extremely important that tests be of sufficient duration to yield meaningful and representative data. There is particular uncertainty in the testing required to analyze coupled thermal effects of waste emplacement on the host rock and groundwater. Because of the significant impacts on schedules, such long-duration tests need careful planning. The most important step in planning is to determine what kind of information is required in a license application. It is equally important to identify, in advance, how much of the data from a long-term test can be analyzed and extrapolated into the future, prior to the completion of the test. The test plan should discuss how the data from such long duration tests (if any) will be used in the repository design.

4.6. Schedule of Testing

Many phases of in situ testing are required to continue during the siting, design, construction, and operation stages. Because of the long lead-time of some tests, schedule of testing will be crucial to the licensing activity. When a construction authorization application is submitted for a particular site, that application must be complete and fully supported by the data and analyses necessary for a decision on construction authorization. It is essential that fundamental test results must be in place at the time of license application. It will be necessary for the applicant to identify which tests will be completed at the time of construction authorization application, and which

tests will continue after that. Any planned long-term monitoring activities should be identified and discussed in the test plan.

4.7. Amount of Testing

Decisions related to establishing the amount of testing should be made on a site and design-specific basis. The amount of testing can vary significantly depending on the objective, nature and scope of the tests. Several different tests can be used to obtain the same rock parameters. For example, the plate test, pillar test, and block test provide sufficient information to calculate the material modulus. For gathering the same set of data, there can be several test methods. Each test can be repeated a number of times depending on the required level of confidence. The same test may be repeated at a number of different locations to assess the variability of the measured parameter. Furthermore, tests may be conducted under a range of conditions to represent the extremes of the anticipated environment. For example, a range of temperatures and confining pressures can be applied to cover the anticipated repository conditions.

The in situ test plan should include criteria to determine whether an adequate amount of testing has been performed. For all tests important to performance assessment a general guidance is that testing should continue or be repeated until confidence in the results is established by an independent peer review.

4.8. Special Testing

Under this discussion "special tests" refer to the unconventional and/or nonstandard tests; for instance, accelerated tests to simulate long term effects in a short duration test period, and tests to assess interactions among different processes, such as, thermal-mechanical-hydrological-geochemical effects. These types of tests, if conducted could raise several difficult questions regarding their appropriateness, adequacy, and procedures. In order to minimize delays during licensing hearings, a careful and logical approach should be followed in identifying the need for such complex tests and defending the data obtained from them. One of the major difficulties that could arise would be the lack of confidence in the measuring techniques and instrument performance under adverse conditions of heat, moisture and radiation. The test plan should discuss the need for and the rationale behind such complex tests and present details on how the data will be used.

4.9. Sufficiency Criteria

The design of a geologic repository is governed by the 10 CFR 60 requirement of a 'multiple barrier' approach. The amount of testing required for individual components of the barrier system should depend on the amount of credit assigned to the individual components in meeting the performance requirements. Under certain conditions, little or no testing of a certain component of a barrier may be acceptable. For example, if no credit is taken in the design for performance of a certain component of the repository system and an appropriate level of conservatism is built into the overall system, then, limited testing of that component may be sufficient. Because coupled thermal-hydrological-mechanical-chemical (THMC) processes is an important issue, the test plan should either provide for direct testing of the coupled behavior, or demonstrate that testing of the coupled behavior is not needed. The need for coupled testing should be based on site-specific conditions (see NRC comments on BWIP ESTP, Reference No. 12). The following guidance can be useful in deciding when direct testing of coupled behavior in the near-field may not be required:

a. Components of the natural system (i.e., geologic, hydrologic and geochemical characteristics) for which performance credit is taken, are characterized adequately for evaluation of overall repository performance;

b. In evaluating overall repository performance, no credit is taken for the near-field host rock which may not be amenable to detailed characterization;

c. Components of the engineered barrier system, such as the waste package, are designed with adequate conservatism with respect to the coupled behavior that will be encountered. Examples of conservatism in design could include: (1) limiting the host rock thermal loading; and (2) thickening of waste container walls; and

d. The tests that support the design of the engineered barrier system are carried out under a much wider range and more adverse conditions than anticipated. This means that the design of the tests takes into account conditions above and beyond the full range of coupled thermal behavior that are expected to be encountered.

4.10. Presentation and Documentation of Test Data

The presentation of the information obtained from in situ tests is a very important phase of the test program. Both raw and processed data should be documented in a clear and logical manner so that:

- o The data can be independently checked for precision, accuracy, and quality by others.
- o The data are in a form suitable for application in descriptive and predictive models, to allow for independent interpretations.
- o All measured ranges (if possible with distributions) of data are clearly presented to allow a deterministic as well as probabilistic performance analyses.

5.0 SUMMARY

This draft generic technical position presents guidance to DOE on what NRC considers to be the essential elements of an in situ test program to address the requirements of 10 CFR 60. The staff considers that necessary and sufficient in situ testing should be performed at depth on the host rock to address the key issues prior to submitting a license application. A rational, methodical in situ test plan should be developed in advance of the exploratory shaft construction. Such a plan must: 1) address the site issues that have to be resolved by testing, 2) provide a rationale for testing, 3) categorize the testing, whether preliminary, part of site characterization, or performance confirmation, 4) describe the tests, 5) provide the criteria by which a determination can be made whether sufficient tests are conducted, 6) outline schedules and duration of various tests and their relationship to the site selection and licensing schedule set by the Congress, 7) delineate whether complex, thermal-mechanical-hydrological-geochemical tests will be performed; if not, provide reasons for such decision, 8) present the logic for selection of a particular scale of testing, 9) specify how much credit is taken for the performance of important components of the barrier system, engineered or natural, and 10) discuss the type of analyses to be applied to the test data.

This technical position is generic in nature and thus covers in situ testing for all potential repository sites and/or designs in a general way. However, the DOE must develop site-specific in situ test plans. Because of the dynamic and evolving nature of the waste disposal program, consultation between NRC and DOE must be a continuous process. If found necessary and warranted, NRC will provide further guidance to DOE on generic and/or site-specific issues relating to in situ testing. These will be accomplished through periodic meetings, site visits, workshops or formal NRC technical positions.

6.0 KEY REFERENCES

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2. Letter from O. L. Olson, Project Manager, Basalt Waste Isolation Project Office to Dr. R. J. Wright Senior Technical Advisor, High-Level Waste Technical Development Branch, Division of Waste Management, US-NRC, Washington D.C. 20555, May 11, 1983.

3. Robert J. Wright, Senior Technical Advisor, High-Level Waste Technical Development Branch, Division of Waste Management US-NRC Notes of NRC/DOE Meeting in Richland, WA, June 9 and 10, 1982.

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11. Federal Register, Vol 46 No. 37, Rules and Regulations, February 25, 1981.

12. Basalt Waste Isolation Project, Exploratory Shaft Test Plan, SD-BWI-TP-007, Rockwell, November 9, 1983.

13. Letter from R. J. Wright, Senior Technical Advisor, Repository Projects Branch, Division of Waste Management US-NRC to O. L. Olson, Project Manager, Basalt Waste Isolation Project Office, US-DOE, re: follow-up comments on the Exploratory Shaft Test Plan, BWI-TP-007, March 9, 1984.

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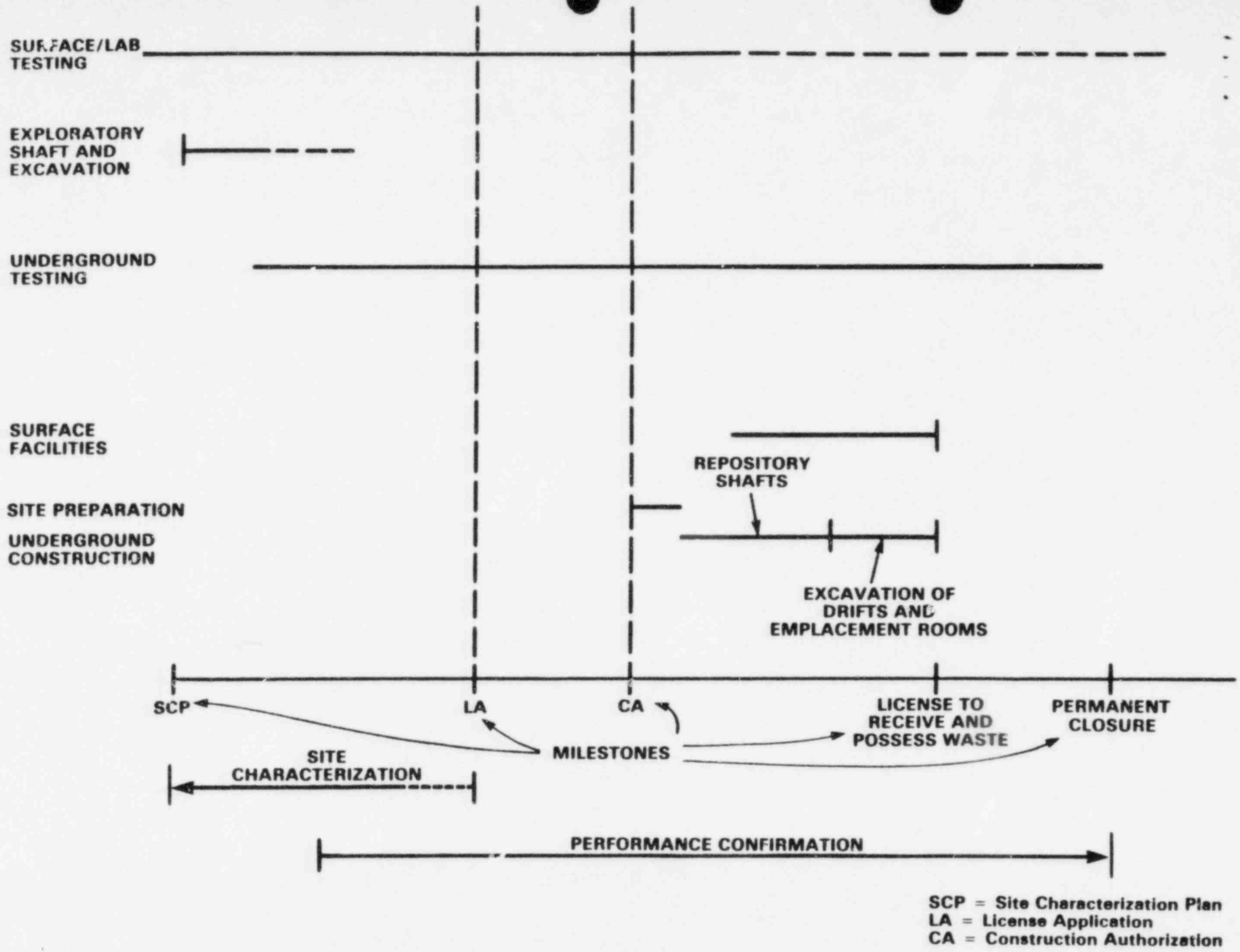

Figure 1 A SCHEMATIC OF SITE ACTIVITIES AND/OR TESTING MILESTONES

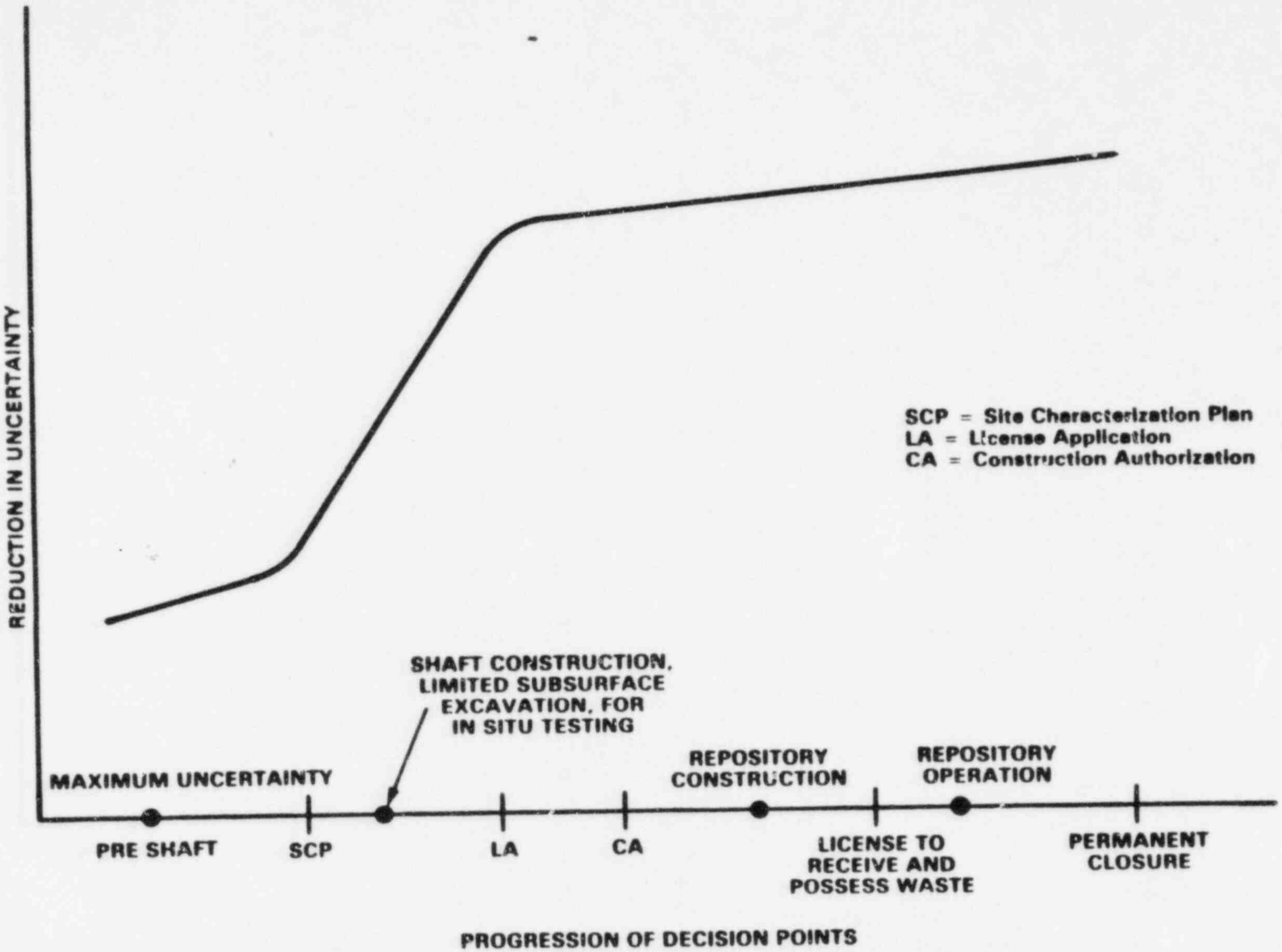

Figure 2 REDUCTION OF UNCERTAINTIES ABOUT COMPLIANCE WITH 10CFR60 PERFORMANCE REQUIREMENTS

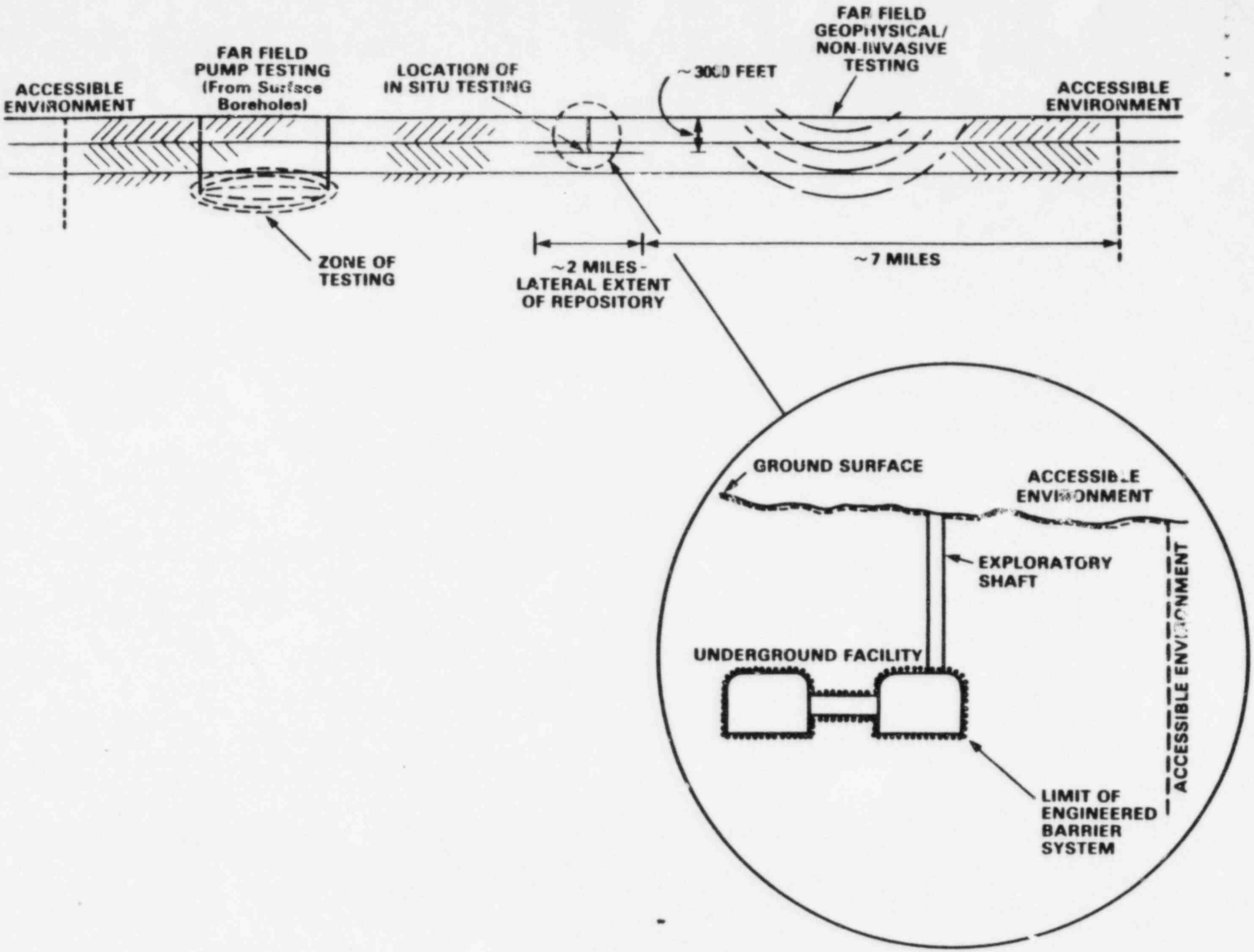

Figure 3 FIELD TESTING (ILLUSTRATIVE)