GENERAL TECHNICAL POSITION ON
IN SITU TESTING PRIOR TO CONSTRUCTION AUTHORIZATION

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1.0 BACKGROUND

The NRC has consistently encouraged and supported in situ testing as a specific activity during Site Characterization. The NRC's position on in situ testing has been established in a series of documents in the recent past (reference Attachment 1). This concept on testing has been put forward for public review and comment. The section of the Procedural Rule (10 CFR 60) containing supplemental information provides a discussion on in situ testing as part of an essential plan by DOE to obtain sufficient data to determine the suitability of a medium to host a geologic repository. The discussion emphasized the NRC's decision to require in situ testing as part of 10 CFR 60.

The Commission interprets "in situ testing" to mean the conduct of geophysical, geochemical, hydrologic, thermal and mechanical tests from shafts and/or underground openings on material forming part of the physical entity and environment of the actual proposed repository site. The object of these tests is to obtain data, which when integrated with the data from laboraoty tests and with predictive modeling capabilities will establish both the values and predictability of the hydrologic, geochemical and thermomechanical reponses to the construction, operation and long term performance of a repository. Ultimately, the objective is to determine the suitability (measured in terms of regulatory standards) of a particular site for a geologic repository.

The main purpose of this Technical Position is to provide guidance to DOE on the requirements, as perceived by the NRC, considered necessary in formulating the scope and nature of an in situ testing program to meet the standards or "quality" in repository performance prediction which are appropriate at the time of the License Application for Construction Authorization. A primary goal of this Technical Position is to indicate to DOE that the level of

confidence in the results of the data analyses must be sufficiently high such that the NRC is allowed to establish "reasonable assurance" at the time of the license application. This approach precludes the necessity of having to speculate on the resolution of important issues and on the assessment of performance objectives when licensing proceedings commence.

For this purpose, guidelines are presented which clarify, based on the available technology, the scope and nature of the in situ testing as a part of the Site Characterization. These guidelines may be revised as the licensing perspective evolves or in response to change in the technical state-of-the-art of in situ testing.

2.0 REGULATORY FRAMEWORK

The Final Rule (10 CFR 60) allows in situ testing, underground investigations, tests and data analysis to proceed prior to formal licensing procedures. This flexibility in the programming of the in situ testing has been provided to allow for the construction of shafts, excavation of tests facilities and performance of in situ tests at the earliest possible time. Flexibility is also allowed with regard to the selection and conduct, by DOE, of a variety of mutually compatible test methods and techniques in order to resolve key issues during site characterization. The basis for this approach is that in optimizing both the level of accuracy and uncertainty of predicting repository performance and resolving key issues, the in situ test program must be defined in the context of the particular site-specific geologic conditions, the characteristics of the predictive models available and the key issues relevant to the site.

The Final Rule (10 CFR 60) clearly states NRC's position on in situ testing and directs DOE to the following requirements:

60.10 Site Characterization

(d)(2) Subsurface exploratory drilling, excavation and in situ testing before

and during construction shall be planned and coordinated with geologic repository operations, design and construction.

60.11 Site Characterization Report

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

60.21 Content of Application

(c)(i)(ii)(f) The Assessment shall contain ---

(f) An explanation of measures used to perform the assessments required in paragraph (A) through (D). Analysis 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.

TECHNICAL POSITION

The NRC's Technical Assistance Projects have been aimed at the single purpose of identifying and obtaining information needs for licensing. The focus of two NRC contracts were on large scale testing needs. These contracts, undertaken by Golder Associates Inc. (GAI) and Lawrence Berkeley Laboratory (LBL), specifically addressed the scope and nature of surface, exploratory shaft and in situ testing needed to resolve key hydrologic and geotechnical issues related to site suitability. The principle reports that address the in situ testing issues are NUREG/CR-3065, "In Situ Testing Programs Related to Design and Construction of High-Level Nuclear Waste (HLW) Deep Geologic Repositories," and NUREG/CR-2983, "Selected Hydrologic and Geochemical Issues in Site Characterization." These reports have been carefully developed and have been reviewed by various technical groups including the U.S. Geological Survey (USGS). A complete list of key references used in the Draft SCA which covered the issues of in situ testing is attached to this letter (Reference

Attachment No. 2).

In situ testing may respond to information needs by either directly simulating certain aspects of the repository or by improving performance predictions (by assessing characteristics and verifying predictive models). The two basic types of site characteristics which form part of the data required for performance assessment are:

- o those which describe the geologic setting (by way of example in situ hydraulic potential, stress and temperature fields, stratigraphy and geologic structure, and tectonics);
- o those which describe the response (engineering) characteristics of the site (by way of example permeability, deformability, and thermal conductivity).

A collective evaluation of these two types of characteristics with the aid of suitable verified models will allow the behavior of the engineered geologic repository to be predicted with reasonable assurance.

In situ testing plays a dominant role in the preparation of data to establish technical consensus and thus "reasonable assurance". This is because of the potential natural variability and complexity of rock masses and the current state-of-the-art of geotechnical sciences in synthesizing the behavioral response of a complex structure such as a repository from that of the individual material elements. However, other data sources and steps (i.e. predictive modeling and laboratory testing) are involved in the resolution of key issues and these sources and steps must be integrated with in situ testing in order to establish what in situ test program adequately complies with the requirements for "reasonable assurance". This systems approach to the definitions of the scope and selection of in situ tests is necessary because ultimately, the objective is to resolve key issues on repository performance according to certain standards with regard to the accuracy and uncertainty of the repository performance prediction. Since this is a sub-set of this overall system, the scope of each in situ test and the entire program is thus controlled by the predefined accuracy and uncertainty of the test results.

This view of the role of in situ testing is valid for either full scale simulation tests or large scale tests for assessing characteristics, since in both cases, extrapolations in time and space to predict repository performance are required.

The basic tenet of this Technical Position is that the design, execution and data evaluation of the in situ testing must be formulated within an overall defensible rationale for resolving key issues. This is necessary because:

- o a defensible logic must be provided for the analysis and decision process leading to the identification of the key issues, so that a technical consensus can be established;
- o encountered conditions in situ may differ substantially from those assumed and thus a rational approach to revising the information needs must be available. Also the perception of information needs may change with time. This requires the existence of a framework for continually revising the testing requirements (in terms of both acceptable accuracy and uncertainty);
- o there must be a clear understanding of the rationale for the selection of tests and the application of data in the predictive models so that the uncertainty in performance prediction can be assessed. This implies that the objective of the in situ testing is not only to obtain predictions of repository performance but also a clear and explicit estimate of the accuracy and uncertainty of these predictions.

When dealing with constructions in geologic media, uncertainty is inevitable. This must be explicitly recognized. This involves not only establishing a consensus on, for example, virgin in situ stress field, but also to have adequate data to enable a consensus to be reached on the likelihood or probability of encountering various discretely different stress fields within a range of possibilities. Because uncertainty exists in data derived from laboratory and in situ tests as well as in the predictive models themselves, the standards for the quality of data to be produced from the in situ tests can only be formulated from an appraisal of the overall data base.

One defensible and rational approach to the selection and design of tests forming part of an in situ test program has been presented in NUREG/CR-3065 "In Situ Testing Programs Related to Design and Construction". In summary, this rationale consists of:

- o establishing the information needs for License Application so as to improve accuracy and reduce uncertainties in repository performance prediction to acceptable levels;
- o assessing the capabilities of available tests;
- o matching the capabilities of available tests to the perceived information needs;
- o developing and validating tests where the test capabilities are currently insufficient;
- o conducting the in situ test program.

Tests may satisfy information needs either by:

- o simulating various aspects of the repository construction/operation;
- o assessing the site characteristics (e.g., hydraulic conductivity) for use in numerical modeling of repository performance;
- o providing direct verification of predictive numerical models.

The information needs at any time result from the necessity to reduce the uncertainties in the prediction of repository performance. The additional information judged necessary to improve the predictability of performance will be a function of the significance of each characteristic to repository performance and the capability for reducing the level of uncertainty, using improvements in data or modeling capabilities, in that particular characteristic.

A rationalization of the interplay between the significance of characteristics and capability of tests assisted by the development of probabilistic alogorithms relating in situ test parameters and performance prediction parameters, can be used to determine an optimum set of in situ tests and the scope of each test.

Both information needs and test capabilities will change with time as a result of :

- o the supplementing and updating of available information;
- o improvements in the capabilities of tests;
- o improvements in the nature of other performance prediction algorithms.

Thus, the in situ test program will evolve with time and should be flexible enough to accommodate such changes efficiently.

The approach should be implemented on a site-specific basis, particularly with regard to information needs. The recommendations in terms of in situ testing requirements should be continually reviewed according to changing information needs, and the developing nature of the investigations.

The following guidelines are presented as to the general scope of the in situ test program perceived by the NRC on the basis of existing testing technology and information needs.

1. General

- the development of underground openings of suitable layout and sufficient extent to properly assess site variability and minimize and account for interference for testing and the demonstration of construction aspects in the proposed repository horizon
- core drilling and geologic mapping of sufficient extent to establish the variability of the significant properties and the representativeness of the in situ test site to that of the proposed repository
- hydrological, geomechanical and thermomechanical testing on a dimensional base sufficient to overcome respective scale effects and truly represent the behavior of an inhomogeous and discontinuous rock mass.

2. Hydrological

- measurement of all significant hydrologic parameters on both local and repository scales using borehole and large scale coupled hydraulic/thermal/mechanical loading tests.

3. Geochemical

- sampling and in situ testing to support laboratory studies of all significant geochemical conditions and phenomena (including radionuclide transport), so as to provide a reliable data base for modeling studies, including temperature effects.

4. Geomechanical

- geological mapping for properly designing and interpretting in situ test and other test as required
- validation and demonstration of construction and full scale response of underground openings and backfill by simulation (e.g., mine-by test).
- representative volume testing (e.g., block tests) to determine the constitutive behavior (strength and deformability) of the host and appropriate adjacent materials.
- direct measurement of the in situ stress field, to supplement if necessary, available data so as to achieve a reliable estimate of the stress field.

5. Thermomechanical

- thermal loading tests (e.g., small and large scale heater block tests) to reliably support modeling studies of repository scale temperature effect and to establish by simulation cannister scale temperature behavior.

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

- the significance of the data in the context of the approach to in situ testing is explained
- re-analyses of the basic instrument data can be performed as a check on the data processing and interpretations
- the data is in a form suitable for application in predictive modeling
- independent review of the test program and its results can be carried out
- probabilistic evaluations of the uncertainty and reliability of any one parameter value can be undertaken

Discussion

Site Characterization consists of a combination of (a) investigations (e.g., drill holes) at the surface and (b) construction of, and testing in, underground test facilities. Due to the long timeframe involved, it is likely that the construction of an underground test facility may be on the critical path to licensing. In all of these documents considered by the NRC, and in the length of time that has been estimated to complete exploratory construction and testing, the NRC has recognized that not all uncertainties will be eliminated at the time of construction authorization. Therefore, it may be necessary to continue monitoring site characteristics with confirmatory testing through the operational period to extend the predictability of earlier results and as a method of data verification and performance prediction validation.

Construction authorization is key step in the licensing process. It is important that the in situ testing, required by the Rule, is carefully planned, analyses are supported by reliable data, and there is a full and timely disclosure of results for review. This would be a prudent and reasonable approach to developing an in situ testing plan so as to preclude the risk of a long drawn out licensing process. The level of confidence established by the scope and nature of in situ testing, as summarized above, allows the NRC to make a licensing determination with "reasonable assurance" and therefore establish a point from which further discussions would be initiated to reach consensus on the resolution of future issues that may

possibly arise during construction and operation. The staff expects to discuss this technical position with each DOE field office, to resolve any differences on a site specific basis.

ATTACHMENT 1

CORRESPONDENCE AND REPORTS ON IN SITU TESTING

August 1980 - Letter report for Site Preliminary Design Verification Project Plan (SPDV) - American Mine Services, Inc., August 1, 1980

August 1980 - Final Report - Review of Site Preliminary Design Verification Project Plan (SPDV) - Golder Associates, Inc., August 1, 1980

November 1981 - Visit to the Basalt Waste Isolation Project (BWIP) Hanford, Washington

January 1982 - BWIP workshop on Hydrology (In Situ Hydrologic Testing) January 12 and 13, 1982

April 1982 - Repository Site Investigations, Panel Review Meeting, Washington, D.C. April 13, 14, and 15, 1982

April 1982 - Martin to Coffman letter on In Situ Testing and Site Characterization, April 15, 1982

May 1982 - In Situ Testing Meeting Report Entitled "Site Characterization Tests and Information Needs for License Application."

June 1982 - BWIP workshop on In Situ Testing DOE/NRC, June 9, 10, and 11, 1982

January 1983 - NUREG/CR-2983 Selected Hydrologic and Geochemical Issues in Site Characterization for Nuclear Waste Disposal, LBL

March 1983 - NUREG/CR-3065 - In Situ Testing Program Related to Design and Construction of High-Level Nuclear Waste (HLW)

March 1983 - Draft Site Characterization Analysis of the Site Characterization Report, BWIP NUREG-0960

May 1983 - Response to Wright/Olson letter on in situ testing, clarification of BWIP SCR (SCR-16)

ATTACHMENT 2

Key Reference Reports, Draft SCA (BWIP)

1. In Situ Testing Programs Related to Design and Construction of HLW Deep Geologic Repositories, Task 2, Vol. 1 and 2, NUREG/CR-3065, Golder Assoc., March 1983.

2. Evaluation of Alternative Shaft Sinking Techniques for HLW Deep Geologic Repositories, Task 3, NUREG/CR-2854, Golder Assoc., March 1983.

3. Relationship of an In Situ Test Facility to a Deep Geologic Repository for HLW, Task 4, NUREG/CR-2959, Golder Assoc., March 1983.

4. Selected Hydrologic and Geochemical Issues in Site Characterization for Nuclear Waste Disposal, NUREG/CR-2983, Lawrence Berkeley Laboratories, January 1983.

5. Letter from J. B. Martin to F. E. Coffman, regarding development of site characterization test facilities at depth, dated April 15, 1982.

6. Memo from R. J. Wright to Distribution, documenting meeting notes on in situ testing needed at BWIP, dated August 9, 1982.