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David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
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Dear David:

Enclosed is our review of "Task V, Engineering Study No. 8, In Situ Instrumentation" by RKE and Parsons, Brinkerhoff, Quade and Douglas (SD-BWI-ES-017). Please call me if you have any questions.

Sincerely,

Roger D. Hart
Program Manager

cc: R. Ballard, Engineering Branch
Office of the Director, NMSS
E. Wiggins, Division of Contracts
DWM Document Control Room

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ITASCA DOCUMENT REVIEW

File No.: 001-02-31

Document Title: "Task V, Engineering Study No. 8, In Situ Instrumentation." (SD-BWI-ES-017, July, 1984)

Author: Raymond Kaiser Engineers and Parsons, Brinkerhoff, Quade and Douglas, Inc.

Reviewer: Itasca Consulting Group, Inc. (M. Board)

Approved: Loren Lorig

Date Approved: 15 May 1987

Significance to NRC Waste Management Program

This document reviews the In Situ testing program conducted in the past (NSTF) and that projected for the ES facility. The tests are reviewed for advantages and limitations, and suggestions made for future testing techniques and instrumentation methods. The recommendations made within this report, if implemented by BWIP, set the plan for instrumentation methods and development for the ES facility as well as confirmation testing and pre- and post-closure repository monitoring.

Summary

The objectives of this study are:

1. Identify geomechanical data requirements for the Nuclear Waste Repository in Basalt.
2. Define appropriate methods for acquiring the data identified.
3. Examine instruments available for use in data acquisition and define needs for improving or developing new instruments.

The above objectives pertain to time frames from ES facility development through the termination of the repository license.

Initially, the report discusses the geomechanical and hydrological data needs for design and pre- and post-closure performance assessment. A strategy for acquiring data to satisfy these information needs is presented. Two broad information needs are given:

- Predict the response of the geologic system to the construction and operation of the repository
- Predict the performance of the engineered materials under the loading and environmental conditions of the repository.

The following individual data needs are then given to satisfy these broad goals:

- A characterization of the regional geology, hydrology, geochemistry, and seismicity of the Hanford Site and its environs
- A detailed characterization of the geology, hydrology, and geochemistry of the reference repository location (RRL) (see Figure A-1 for repository location map)
- The constitutive, hydrologic, and geochemical properties of the rock in and around the candidate repository horizon (at-depth repository location in the candidate flow)
- The characteristics and properties of the nuclear waste form, the waste package, and the engineered materials used in repository construction
- Measurements of the response of engineered materials within the repository and the geologic system surrounding the repository to repository construction and operation.

These information needs are then satisfied through several phases of data gathering:

1. Surface and near-surface exploration and testing, including laboratory tests of coring and the NSTF testing.

2. In situ testing at repository depth prior to construction.

3. Exploration in the repository horizon before construction.

4. Monitoring during repository construction and operation.

5. Confirmation testing in the repository horizon.

6. Post - closure monitoring.

For each phase given above, the data to be gathered are given (i.e., Young's Modules, strength, etc.), the accuracy with which this property or phenomenon is to be measured is listed and the suggested in situ testing techniques are described. For each in situ test, the instrumentation is described in some detail. The accuracies, limitations and advantages of each instrument is described, eventually leading to a set of conclusions regarding improvements in instrumentation techniques required for the repository testing and monitoring.

Recommended instrumentation efforts include:

1. Research and development of a deep flatjack test using a saw-cut slot and high pressure (35 MPa) flatjacks.

2. Improvement of the USBM borehole pressure cell for use in stress change monitoring.

3. Development of a soft-inclusion strain cell for borehole stress change measurements.

4. Perform a triaxial strength test on a 300 mm (12") diameter core in situ. This test requires confinement through curved flatjacks and a large set of hydraulic jacks.

5. Improvement of the rod extensometer through use of low-expansion materials.

6. New or improved methods for measurement of transverse displacements in high temperature environments.

7. Improved packers, plugs and pressure transducers for high temperature hydrologic monitoring.

8. Improved high temperature accelerometers.

9. Compact seismic frequency-modulated wave source for use in underground seismic profiling.

10. Development of ground-probing radar for sensing anomolies in advance of excavation.

11. Development of electrical resistivity for sensing anomolies in advance of excavation.

The document is, in effect, a test plan for ES and confirmation testing and has several positive attributes. An attempt was made to show the integration of the design and performance assesment data needs to the lab, NSTF and at-depth testing. An attempt was made to determine the range and accuracy necessary in the measurement of the needed properties. This range and accuracy are further used for specification of instrumentation types. A logical process is therefore used to arrive at the eventual conclusions regarding needed instrument development.

Several interesting points were made by the authors of this document in their discussion of testing needs, including:

1. The lateral and vertical variability of the Cohassett flow and its effect on rock mass response, design and performance assessment is recognized by the authors. They suggest that the extent of the ES facility ($\approx 25000 m^2$) is far too small to be representative of geologic anomolies in the repository ($\approx 7.7 x 10^6 m^2$) - about 0.3% of the total repository area. To quote the report: "To establish a definitive repository design, therefore, extended lateral exploration in the repository horizon will be required prior to construction," (page 65). In fact, the report suggests that exploration drifting proceed immediately upon completion of the ES-II shaft and that it proceed in parallel with the exploratory shaft testing. It is recommended (page 65) that

lateral exploration encompass one quadrant of the repository (the area required for five years of waste receipts) prior to completion of definitive repository design. Exploration would then be extended in similar stages so that at all times lateral exploration would be five years in advance of future waste receipts. The plan calls for perimeter drifting with 2.5m diameter drifts around the emplacement zone, crosscutting through it and drilling of boreholes and use of geophysics to fully explore the area prior to waste emplacement. This plan has a great deal of merit, and is similar to the extended exploration suggested in the recent point paper on in situ testing at Hanford (Itasca, 1987). To our knowledge, however, such thinking has not been incorporated into the BWIP testing plan which still calls for only a small series of drifts and four 300m horizontal boreholes.

2. The document sets out the suggested plans for confirmatory testing and repository monitoring to verify that design and performance objectives have been reached. There are four major components in this program: (1) Detailed evaluation of geologic conditions immediately prior to and after excavation of full-scale repository openings; (2) Monitoring of the performance of repository openings and rock support systems following repository construction but prior to waste emplacement; (3) Confirmatory testing in a prototypical section of the underground repository that reproduces all features of the design, construction, and operation of a representative element of the waste emplacement panels; and, (4) Global monitoring of performance after emplacement until closure.

3. The document suggests only a few basic changes to the present BWIP test plan which are of little consequence (with the exception of extended exploration drifting.) A rather expensive triaxial test on an in-place, 300mm (12") diameter core stub (still fixed at hole bottom) is suggested. Little is to be gained from such a test. More on this point is given in the discussion on limitations.

4. A great deal of discussion deals with required accuracy for the knowledge of properties such as deformability, expansion, etc. However, there are no back-up calculations for the assertions, and it is obviously not a trivial "engineering judgement" exercize to define such accuracy limitations.

In conclusion, the document provides an attempt by a BWIP contractor to approach (logically), the specification of testing and instrumentation needs for future at-depth testing. The document presents a better analysis of data needs for ES testing than does the BWIP testing plan (BWIP, 1984). The primary drawback is that little change was made in the test specification from the original BWIP plan.

Problems, Limitations, Deficiencies

There are several significant problems with the document. These are listed below:

1. ES Testing - The document discusses at some length the variability of basalt, and the effects of jointing on rock mass properties. Still, no strides are made to suggest the advantages of full-scale prototype testing as opposed to the point testing approach described in this document as well as in the BWIP testing plan (BWIP, 1984). As discussed in Itasca (1987), the inhomogeneity and possible anisotropy of the basalt leaves little choice except the performance of large scale, prototype thermomechanical testing for validation of design and performance models and confirmation of design criteria.

2. The document assigns the "acceptable" accuracies required in all rock mass and laboratory properties for use in design and performance assessment. For example, a 30% accuracy in knowledge of rock mass strength is termed "acceptable". First, there is no analytical or empirical back-up given for these figures. Apparently, they are derived from "engineering judgement". The implications of these for design and testing figures is rather important, and must be supported through parametric analysis, i.e., a certain percentage change in a property must be related to its effects on performance and design.

To our knowledge, such a study has not been completed by BWIP. Second, it is very difficult to define or measure many of the properties which are required. For instance, what is the definition of rock mass "strength". Is it a non-violent yield characterized by slip on joints or is it a violent failure such as a rock burst or collapse. In mining terms, a "strength" associated with pillars is more likely to be the latter. Therefore, it is not a simple matter to measure "strength" in situ, and then assign acceptability criteria to it.

Another example is the measurement of in situ stress, which is to be known within an "acceptable accuracy" of ±40%. Again, accuracy implies a method of calibration of the measurement technique against some known value. It is therefore not possible to determine the absolute accuracy to which one knows a quantity such as in situ stress.

3. The primary end-product of this document is a listing of tests and instrument development for ES planning purposes. Very little discussion is given regarding quality assurance procedures which must be followed during the various stages of instrument materials selection, fabrication, calibration and testing, installation, data acquisition and reduction, analysis and recalibration.

4. Validation of models from in situ testing and construction data is mentioned only in passing as though it were standard procedure. BWIP needs to tackle the problem of what constitutes model validation and what levels of confidence or agreement are necessary in comparison of models to field data.

5. The problem of rock mass "strength" arises again in this report. BWIP's present approach to determination of a rock mass strength is to: (1) Fit the Hoek-Brown criteria to intact triaxial strength; (2) Use Rosengren and Jaeger reduction factors to determine size effect; (3) Further reduce strength with an excavation size effect term. The document proposes a new triaxial strength test in situ by coring a 12" diameter core of basalt, placing curved flatjacks in the annulus between the rock and core, and

compressing the core axially with hydraulic jacks. Due to the heavily fractured nature of the rock, it is questionable if a 24" long core would stay in one piece. At the least conservative guess, the uniaxial strength of the core may be around 100 MPa. This would require axial loads in excess of 3.6 x 10^5N (1.5 x 10^6 lb). The strength increases rather dramatically with even slight confinement, and axial forces in excess of 5 x 10^6lb would be necessary. We are aware of only one or two testing machines which exist in the U.S. with force capacities this great. For the great expense involved in such a test, one would retrieve very little data, i.e. how much better is the strength of a 12" core as opposed to a 4" or 6" core? Again, the approach should in our opinion, be toward large scale prototypical demonstrations rather than small, point-scale testing.

6. The report takes an unrealistic view to the accuracy of determination of some parameters. For example, an "accuracy" of determination of 15% is required on hydraulic conductivity measurements, however, the estimated range of the parameter is eight orders of magnitude (page 112). Does this mean that a knowledge of hydraulic conductivity of ±.15 x 10^8 is acceptable?

7. The deep slot flatjack test is suggested as a means of measuring in situ stress. This requires a measurement of deflection perpendicular to the flatjack. It is unlikely that the deflectometers will provide an accurate enough measurement since it will not be possible to drill holes in close enough proximity to the slot without inducing failure in the slot.

Detailed Comments

page 58	The need to examine room stability and performance for varying intraflow structures is not discussed.
page 62	The restriction on extent of testing (a major point of limitation in this document) is tied to the size of shafts and to the schedule, not for technical reasons.

page 67	The document puts forth geophysical testing methods as a means of being able to determine if the rock mass is within "design limits". We assert that it is not possible to make such conclusions from geophysical testing. No discussion is given as to what is meant by "design limits".
page 70	The depth and characteristics of the DRZ is to be determined by geophysical methods such as refraction and reflection seismology and cross-hole ultrasonics. These methods require a relatively sharp demarcation in properties between the zone to be detected and the host rock. Unless the rock is significantly loosened, it is often even difficult to see this zone even from inspection of core or the borehole. The changes are too gradual to see with geophysical techniques.
page 72	The document states three conditions for license application for receipt of nuclear waste, but does not reference them.
page 77	The definition of validation given is different from the standard usage.
page 83	The anomolies present are important, not only from a water inflow standpoint, but also from a stability standpoint. Faults or other large-scale features can result in stress concentrations at the face, and rock burst or other stability problems.
page 90	Expected maximum closures of 30mm do not assume possible unstable ground resulting in slip on joints.
page 108	As stated in the major comments section, table 3.2 often ties "acceptable" accuracies of ±15 - 30% on parameters which vary by 50 - 100%. It seems a bit non-sensical to apply a 15% accuracy to some property which is: 1) ill defined (such as strength); 2) something which there are no standard techniques for measurement of and; 3) may be a non-linear function of several variables.

page 110 An "acceptable" accuracy of field measurement of thermal expansion of 10% is stated with a lab value of 5 - 7 x 10-6 and a field measured value of 5.7 - 7 x 10-6. This ignores the fact that the NSTF horizontal displacements from the heater tests were off by over 100% in many instances, and that the reported thermal expansions from the heated block test are from selected instruments. Some displacements from this test even had the wrong sense of direction.

page 114 Maximum water inflow of 500gpm for repository does not agree with the 3500gpm possible event from the FEA.

pages 132 to 145
The plate-bearing and flatjack tests at the rock surface will yield deformation moduli for the blast-damaged and stress fractured skin of the opening, and appear to be of little use in design.

page 176 The CSIRO cell is highly temperature sensitive.

page 199 An in situ direct shear test in basalt would be exceedingly difficult to perform due to the heavily fractured nature of the rock, which will make sample preparation difficult.

page 240 The digitizing and recording of all A/E signals would be a horrendous job in real time due to necessity for exceedingly fast computation. Source location of events for a planar array of geophones will be difficult.

page 245 Again, seismic refraction is probably not a meaningful technique for determining disturbed zone depth.

page 272 The accuracy requirements on the convergence meters and the deflectometers is not realistic. Convergence meters have significant inaccuracies in resettability and linkage, whereas the errors for deflectometers are cummulative along the length of the instrument, and are highly susceptible to blast vibration.

page 284	Hydraulic anchors are probably preferrable to most investigators. It seems highly improbable that the C-ring anchor would provide a better, long-term anchorage against slippage. Groutable anchors are probably not the best for highly-accurate displacement measurement.
page 289	The table here examines the advantages and disadvantages of various displacement transducers. It is actually quite inaccurate. Such well known, standard devices as LVDTs, DC-LVDTs and linear potentiometers are listed as "complex". This is ridiculous.
page 307	The tabulated values of instrument accuracies are highly suspect since the accuracy, in most cases, appears to be that of the transducer alone, not the entire instrument. All geotechnical instruments must be installed into the rock mass, and many have rather elaborate linkage mechanisms (deflectometers, extensometers, vibrating wire stress meters.) The true accuracies of these in situ is not known since there is no true way of calibrating them.

Recommendations

No further recommendations are necessary at this time.

REFERENCES

BWIP Staff, Rockwell Hanford Operations. "Exploratory Shaft Test Plan, Vol. II: Preliminary Test Descriptions, Rev. 1 (Draft)," SD-BWI-TP-007, Dec. 1984.

Itasca Consulting Group, Inc. "In-Situ Testing at the Hanford Site," ICG report to the NRC, February 1987.