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The U.S. Department of Energy's Crystalline Repository Project- A Technical Overview

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Introduction

The mission of the U.S. Department of Energy's (DOE) Crystalline Repository Project (CRP) is to site candidates for the second high-level nuclear waste repository mandated by the Nuclear Waste Policy Act of 1982 (1). It is the intent of DOE to construct a second respository, after receiving authority as specified in the U.S. DOE Mission Plan (2).

Toward completing this mission, the CRP can be divided into several phases: 1) the national survey, 2) the regional phase, 3) the area characterization phase, 4) the detailed site characterization phase, 5) construction, 6) operation, and 7) decomissioning. The national survey was completed and documented as OCRD-1 April 1983 (3). The CRP is concluding the regional phase which consists of screening approximately 240 rock bodies in three regions (north central, northeast, southeast) to determine approximately 12 areas for inclusion in the area phase. The regional phase was primarily conducted through a literature study of the three regions and screening was based on that data. The results of this screening are documented in the draft Area Recommendation Report released January 16, 1986.

The area phase of the project will consist of field characterization to provide data and information to select approximately three of the 12 candidate sites to be nominated for detailed characterization in the site phase. Area field work is slated to begin January 1987 and to be completed in 36 months. Once the area phase is completed and 3 sites are chosen, detailed site characterization will proceed. The outcome of detailed site characterization will be one site at which the repository will be constructed, operated, and decommissioned.

Systems Methodology Development

The geologic disposal of high-level nuclear waste (HLW) involves a profound and complex political, economic, social, and technical problems. In order to address these complexities, the CRP needs to develop a methodology to collect information and to evaluate that information. Then decisions can be based on sound technical judgement and can be clearly followed by interested parties.

The CRP is currently developing a methodology that can be used during the area characterization phase. The objectives of the methodology are to:

- Provide a means to complying with regulatory requirements
- Identify data and information needs to complete the above objective
- Provide a mechanism for evaluating and comparing areas of interest in order to select candidate sites
- Allocate resources for siting and research needs

The methodology is developed by technical discipline in compliance with the U.S. DOE Siting Guidelines (4). As a result, sector models were developed for, post-closure safety, pre-closure safety, environment impacts, socio-economic mitigation, transportation safety, and overall costs.

The use of sector models will allow the CRP to rate each candidate site on each subject within a sector model. Individual site ratings can then be combined using some type of preference model (to be developed) that will assign weights based on importance to each of the outcome variables of each sector model. An overall rating based on all sector models can be determined and that information supplied to the decision maker for use in selecting sites for further development.

Because of the regulatory approach to the methodology, significant weight will be attached to post-closure safety. Therefore, the collection of information and data necessary to conduct performance assessment activities becomes of paramount importance to the CRP.

Research Activities

The Crystalline Repository Project is currently participating in a number of research projects, some involving international cooperation and some conducted solely by the CRP. These

* Editor's Note: Edward S. Patera's remarks were presented at the symposium by Scott Hinsberger of the U.S. Department of Energy Crystalline Repository Project.

research areas include hydrogeology, geochemical transport, borehole geophysics, and rock mechanics.

The CRP is involved in the OECD/NEA sponsored Stripa International Project as the U.S. representative. This project, conducted in the Stripa iron ore mine in central Sweden, includes research in hydrogeologic characterization, tracer migration studies, cross-borehole characterization development, and backfill and buffer materials development.

The DOE is also cooperating extensively with the Canadians through Atomic Energy of Canada, Ltd. (AECL) on four areas of mutual interest. These areas include: 1) Underground Research Laboratory (URL) shaft deepening and characterization; 2) the URL experimental program; 3) field characterization techniques development; and 4) performance assessment activities.

The first area of cooperation is the extension of the URL shaft from its present depth of 240 meters to approximately the 440 meter level. This would allow construction of laboratory facilities at a depth more appropriate to a repository. In addition, the granite will be characterized to the 440 meter level in the shaft, and a major sub-horizontal fracture zone will be characterized and stabilized.

The U.S. will also cooperate in the planning and performance of a number of experiments within the URL. Potential experiments include the following.

- Excavation response experiment
- Heated block experiment
- Single fracture migration experiment
- Buffer/Container experiment
- Borehole/Shaft sealing investigation
- Pressure chamber experiment

The third area of cooperation is the CRP's participation in AECL's hydrogeologic field characterization experiments. The CRP has two objectives for this work. The first is to assist in the field experiments to gain a better understanding of crystalline rocks through the collection of field data and the subsequent performance analysis. The second objective is to test CRP's planned area characterization methods and equipment for use within the identified candidate areas in the U.S.

The last area of cooperation is in performance assessment activities. These include assessments of the research areas as mentioned above for comparison with Canadian results, possible geochemical data generation, and transfer of computer codes between countries.

CRP independently conducts research in the areas of hydrogeology and geochemistry. Within these areas, the research is devoted primariliy to development of computer codes for modelling of crystalline rocks to gain a better understanding of the physical and chemical processes that will be operating within a crystalline HLW disposal system.

One of the most important aspects in demonstrating repository performance is characterization of the hydrogeologic processes. This includes determination of the travel time to the accessible environment, the most likely pathways, fluxes through the pathways and the repository, and the discharge points. All of thse factors are relevant in fractured crystalline rock.

The nature of fluid flow within a fracture medium (versus a porous medium) can represent much uncertainty when an attempt is made to model the disposal system accurately. It is for this reason that the CRP is devoting most of its research resources toward developing an understanding of fluid flow in fractured systems.

The CRP approach to understanding fluid flow in fractures is three-fold. The first is a theoretical treatment of fluid flow in a fracture network. The fracture network is generated randomly based on density, orientation, length, and apertures. The interconnections are calculated and then flow is determined through this network. The mathematical approach is designed to study different parameters of the system and determine when scale effects are most important. For instance, it would be very desirable to know at what volume of fractured rock porous medium equivalents can be used to represent flow within crystalline rock to some specified degree of accuracy.

The second approach to modeling fractured rocks will be rooted in geologic field observations and the fracture or joint set data derived from surface and underground sources. Hopefully, this approach will enable prediction of fracture networks in a given geologic setting based on rock types, tectonic history, in-situ stress of the rock, and other pertinent data. This information, together with the theoretical understanding of fracture networks, will allow the CRP to construct conceptual models of sites with fractured rock and thus to perform more confident analyses of the sites' performance.

The third approach is to use physical models of fracture networks in the laboratory. The objective here would be to validate the theoretical understanding of fluid flow in fracture networks. This would be accomplished by setting up the requisite problems and constructing appropriate physical models.

Research into the nature of hydrothermal reactions has been initiated by CRP as well. The objective of this research is to gain a better understanding of coupled thermal, chemical and flow processes. This aspect of performance assessment is crucial to developing accurate and confident systems performance assessment in order to license a repository in crystalline rock.

The above experiments will be performed in a flow-through hydrothermal pressure vessel. This apparatus will allow the use of temperatures of 500° C and pressures of 300 bars. Fluid of a specified composition is passed through the apparatus once and is collected for analyses at the end of the flow column. Initial runs will use granite and granitic groundwater and will be performed at high temperatures to promote reactions and allow more experiments per unit time. The information derived from the experiments will be 1) the change in groundwater composition as a function of both temperature and flow rate, 2) the change in mineralogy with respect to temperature and flow rate, and 3) the change in permeability of the system as a function of temperature, flow rate and total water flux throughout the system.

Although not planned at this time, this experimental apparatus could be used in conjunction with other materials (waste forms, cannister material, buffer/backfill material) to test the effects these materials would have on groundwater chemistry, host rock degradation, engineered barrier component degradation, and groundwater flow.

Conclusion

The CRP will use an integrated approach to identify information needs to ensure the successful completion of its mission. The nature of crystalline rocks and how they will behave under repository conditions is a complex technical problem. The CRP will continue to support research and development in these areas both domestically and through international cooperation.

References

1. Public Law 97-425. 1983. *Nuclear Waste Policy Act of 1982.*
2. U.S. Department of Energy. 1985. *Mission Plan for the Civilian Radioactive Waste Management Program.* Vol. 1.
3. Office of Crystalline Repository Development. 1983. *A National Survey of Crystalline Rocks and Recommendations of Regions To Be Explored for High-Level Radioactive Waste Repository Sites* OCRD-1. Columbus. OH: Battelle Memorial Institute.
4. U.S. Department of Energy. 1984. Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. *Federal Register.* 49 (236). p. 47714
5. Ubbes, W.F., and Duguid, J.O., 1985. *Geotechnical Assessment and Instrumentation Needs for the Isolation of Nuclear Waste in Crystalline Rocks.* Columbus, OH: Battelle Memorial Institute.
