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Consulting Group, Inc.

8 July 1987

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
FIN D1016

Dear David:

Enclosed is our review of the document "Task V, Engineering Study No. 7, Waste Emplacement Optimization," by RKE/PB (SD-BWI-ES-018, May 1984). 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.: 001-02-32

Document Title: "Task V, Engineering Study No. 7, Waste Emplacement Optimization," by Raymond Kaiser Engineers, Inc. and Parsons, Brinkerhoff, Quade and Douglas, Inc., (SD-BWI-ES-018, May 1984)

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

Date Review Completed: 8 July 1987

Approved: Roger D Hart

Date Approved: July 8, 1987

## Significance to NRC Waste Management Program

This document provides the primary technical calculations which has led BWIP to the decision to use the short horizontal emplacement configuration with one canister per borehole. The document also determines the gross thermal loading density based on maximum allowable waste temperature and rock mass strength. These results have fed into the present conceptual design.

## Summary

In 1983, Rockwell issued its Conceptual System Design Description (CSDD) (RKE/PB, 1983), which represented the first draft of the repository design in basalt. That design called for waste emplacement in long (≈ 200 feet) horizontal boreholes drilled asymmetrically from the emplacement drifts. Each borehole was to contain 13 to 17 waste canisters. The present document re-examines the various alternatives for waste emplacement, ostensibly based on newly-obtained geotechnical data. The subsequent result is a much different emplacement scheme and, thus, repository design. A short-hole (≈ 20 feet) horizontal arrangement, with one canister per hole, is chosen. The 1983 design has been changed radically

to accommodate the smaller pillar dimensions for the short-hole scheme.

The document presents 51 initial variations of waste emplacement which fall under the following general headings:

- horizontal short-hole emplacements with a single canister per hole
    - — holes at right angles to the room with canisters close to the room
    - — holes at right angles to the room with canisters removed some distance into the room
    - — holes at 45° angles to the room
- non-horizontal short-hole emplacements
    - — vertical holes in floor
    - — holes in floor, angled 45° in the direction of the room
    - — holes at floor corners, angled 45° away from the room
- in-room emplacements
    - — pipe surrounded by backfill in room
    - — trench in the floor
    - — self-shielded container in the room
- horizontal long-hole emplacements, with multiple canisters per hole
    - — asymmetrical configuration with constant placement room configuration
    - — symmetrical configuration with alcoves for hole drilling and waste emplacement

For each alternative, a thermal analysis was conducted using the SUPER7T numerical model. The canister pitch required to produce the maximum allowable waste temperature was then chosen for stress analysis. A mechanical and thermal stress analysis is then conducted for the minimum pitch identified by the thermal analysis. The peak compressive stresses induced at the room crown and emplacement holes are then compared to an estimate of rock mass strength determined by the Hoek and Brown failure criterion. It is seen that the strength criterion is more conservative than the allowable temperature and, therefore, controls the canister pitch.

The above studies are supplemented with a determination of appropriate handling methods for waste emplacement and retrieval as well as an analysis of ventilation requirements. The eleven alternatives are then subjected to a comparative evaluation of cost, schedule, safety, and development needs. Long-term waste isolation was not a consideration. In order of preference, the top four alternatives are:

(1) horizontal, short-hole schemes with canisters close to the room, holes angled or normal to emplacement drift;

(2) angled, short holes in the floor;

(3) asymmetric, horizontal long holes; and

(4) angled short holes in drift corners.

Problems, Limitations and Deficiencies

1. This study is not specific to the Cohassett Flow but is developed from a composite data base of the four candidate Grande Ronde flows. The data base of material properties is totally based on laboratory values. The elastic modulus is reduced by 50% in an attempt to account for jointing. The in-situ basalt strength is determined by applying reduction factors developed for thermally-fractured marble (Rosengren and Jaeger, 1969). No in-situ data on material properties has been used in the conceptual design.

2. The in-situ stress state is a critical parameter in the determination of induced stresses around the emplacement rooms. The average maximum horizontal stress is used as input to the modeling. In a recent document review (Itasca, 1986), it was shown that this stress state is not conservative and could potentially underestimate maximum field stresses by 20 to 25%. Because canister pitch is controlled by the drift crown stress, it appears that a conservative estimate of in-situ stress could decrease the allowable gross thermal load by a significant amount.

3. The potential effects of seismicity are not considered in the stress analysis. There are numerous Richter magnitude 4 events in the near vicinity of the Reference Repository Location. The regional stability effects of these events needs to be considered.

4. The analysis conducted here is done primarily from a rock mechanics/mining standpoint. The feasibility of the scheme from a performance assessment standpoint has not been examined.

5. It is interesting to note that the evaluation process results in short-hole emplacement schemes as being of top priority, whereas the 1983 CSDD ranked the long-hole schemes highest. There is very little difference in the geotechnical data base between the two studies, as stated in the Introduction. It appears that fears concerning possible long-hole drilling into a water-saturated intraflow feature, possibly difficult retrieval, and high equipment development cost effectively downgrades the long-hole options.

6. Several problems exist in the thermal and mechanical modeling. These are listed separately below.

   a. The thermal analysis is conducted with an unreferenced code, SUPER7T. The detail given in the description of the analyses (assumptions, code operation, boundary conditions, if any, etc.) is quite poor, and it is extremely difficult to judge conservatism in the results. Apparently, the peak basalt borehole wall temperature is determined as a function of canister pitch. The peak waste centerline temperature is determined analytically as a cylindrical source by knowing the wall temperature. Convection is not modeled explicitly; the air gap conductivity is increased by a factor of two to account for its effect. No reference or discussion is given concerning the reasoning behind this assumption.

b. The thermal stress analysis is performed in two ways: a simplistic equivalent model and a detailed numerical study. Simplistic analysis is conducted in which an average temperature rise for the rock mass surrounding a single canister is determined. This temperature rise is used to determine an equivalent elastic horizontal stress increase, assuming fixed vertical and free horizontal boundaries. This equivalent stress is added to the far-field horizontal stress which, in turn, is used to determine the final induced stress at the room crown and borehole wall using an elastic boundary element approach. This type of analysis tends to smear out the effects of the thermal gradient, developing a spatially-uniform induced stress. The resulting effect is to reduce stress concentration and to ignore the transient tension developed at the drift.

The second form of analysis used is a numerical study in two and three dimensions with the ANSYS code. ANSYS performs a separate thermal analysis which is coupled to the mechanical analysis at selected time intervals. Two constitutive laws were used for the rock mass: elastic and elastic/ perfectly- plastic. The two-dimensional analysis was conducted to analyze the effects of canister heating only, and the boundary conditions were set to reproduce the simplistic thermal stress calculation stated above (i.e., central radial heat source with fixed vertical and free horizontal boundaries). The simplistic and numerical analyses are compared only for the peak induced compression, which compares well. This good comparison is given as justification for the assumption that the thermally-induced stress may be represented as an equivalent far-field horizontal stress. A very coarse three-dimensional ANSYS model of the quarter symmetry of the drift was set up with fixed vertical and horizontal boundaries. Again, the pseudo steady-state comparison of the horizontal stress in one direction is very close to the simplistic analysis.

Both of these models compare well since the boundary conditions are developed to provide the same steady-state solution as the simplistic case. We have not been provided with the other information which may be of great importance, such as (1) the transient stress components during the first year or two after emplacement, and (2) induced stresses in directions other than those compared in the discussion. It cannot, therefore, be stated that the simplistic analysis is justified by the numerical study.

The relevance of the elasto-plastic runs is difficult to determine, as two material types with different stress-strain curves are used to describe the material around the opening (one for close-in material and a different one for further out). The values of cohesion and friction used are not given or referenced. The finite element mesh used to describe the opening is very coarse and may yield poor plasticity solutions. The use of 4- and 8-noded brick elements produced very different results, making the solution suspect. In general, the model and procedures used are very poorly described.

7. The rock mass strength parameters vary significantly between this report and the later 1985 Conceptual Design (RKE/PB, 1985). In the present document, the peak strength for the emplacement hole is 36 ksi and 32 ksi for the emplacement room, whereas the 1985 study uses 29.1 ksi and 22.8 ksi, respectively.

8. The relative weights of importance in the technical evaluation of the emplacement methods rank cost above safety.

## Conclusions

This report ranks the alternative emplacement schemes suggested in the 1983 CSDD. The short-hole horizontal concept is chosen as the best alternative and is, to the best of our knowledge, the scheme used in the present conceptual design. The reviewer agrees that the short-hole concept provides the greatest reliability for safe emplacement and retrieval and requires the least development of new equipment. The methods used to determine rock mass strength and induced stresses are debatable, however, and can only ultimately be assessed through in-situ testing and demonstration.

Recommendations

A draft copy of the Conceptual Design Report should be obtained and reviewed prior to its official release to provide sufficient time for a detailed review.

References

Itasca Consulting Group, Inc. Review of "The State of In-Situ Stresses Determined by Hydraulic Fracturing at the Hanford Site" by Kunsoo Kim, Steven A. Dischler, James K. Aggson, and Michael P. Hardy (RHO-BW-ST-73P), Document Review No. 001-02-21 to the NRC, July 1986.

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