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6 August 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 "Unit Evaluation at Yucca Mountain, Nevada Test Site: Near-Field Thermal and Mechanical Calculations Using the SANDIA-ADINA Code" by Roy L. Johnson and Stephen J. Bauer (SAND83-0030, May 1987). Please call me if you have any questions.

Sincerely,

Roger D Hart

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.: 001-02-38

Document Title: "Unit Evaluation at Yucca Mountain, Nevada Test Site: Near-Field Thermal and Mechanical Calculations Using the SANDIA-ADINA Code" by Roy L. Johnson and Stephen J. Bauer (SAND83-0030, May 1987)

Reviewer: Itasca Consulting Group, Inc. (L. Lorig)

Approved: J Daemen

Date Approved: 8-3-87

Significance to NRC Waste Management Program

The document reviewed is a basic reference used by DOE to justify the choice of the Topopah Spring welded tuff unit for the repository horizon. The work described in the document was completed in 1983 and was cited as a basic reference in Johnstone et al., 1984. It must be recognized that the properties assumed in the calculations were those available in the 1981-1982 timeframe.

As recently as a year ago, the status of the report was described by Sandia personnel as being unknown. It appears that the major reason for releasing this document at this time is to satisfy requirements concerning availability of documents referenced by the SCP. It is not clear whether or not the document will be directly referenced in the SCP. However, the summary document (Johnstone et al., 1984) was listed as a reference in Appendix N (Thermomechanical Calculations) of the draft CDR.

In a companion study by Thomas, who used the JAC code to "validate the ADINA results by performing the same calculations with a different code", [Thomas (1987), p.2], the following conclusions are reached.

1. The ADINA model was "unconservative with respect to predicting matrix stresses".

2. The "comparative results for the JAC and ADINA models are puzzling."

At this point, the document reviewed is primarily of historical interest. Recently, similar calculations to those reported in the document reviewed have been presented by St. John (1987). These calculations use the more recent problem geometries and host rock material properties given in the NNWSI Reference Information Base [TS2 Data, 80% Saturated (Zeuch and Eatough, 1986)].

Summary

The document reports results of thermal and thermomechanical two-dimensional room and pillar geometry calculations for two horizons (Topopah Spring and Calico Hills units) that had been identified as potential candidates for a repository. Calculations for two other horizons (Bullfrog and Tram members of the Crater Flat tuff) were also made but not reported. [Detailed results of thermal and thermomechanical calculations for all units reportedly were archived in the SNL/NNWSI Records File (p. 1)].

All thermal calculations were made using the 1978 version of the ADINAT (Bathe, 1977) computer code. Thermomechanical calculations were performed using the computer code SANDIA-ADINA, a modified version of ADINA (Bathe, 1978) that includes a material model for ubiquitous jointing.

Performance of the horizons was assessed (in Johnstone et al., 1984) on the basis of four different criteria:

(1) radionuclide isolation time;

(2) allowable repository gross thermal loading;

(3) excavation stability during an extended period of heating for up to 100 years; and

(4) relative economics.

This report presents results directly related to the second and third criteria. The calculations performed assumed a vertical emplacement mode. The maximum gross thermal loadings (GTL) were obtained from a series of thermal calculations for each horizon to determine the GTL that would produce a maximum temperature at the room floor centerline of 100°C after a 110-year period of heating.

Based on waste storage capacity as determined by the maximum GTL, the ranking from best to worst of candidate horizons is Topopah Spring, Bullfrog, Tram and Calico Hills. The total difference in the maximum GTL is small—from highest to lowest is only 3 kW/acre. The optimized GTL for Topopah Spring was 56.9 kW/acre. Based on inferred stability, the unit rankings from best to worst are, again, Topopah Spring, Bullfrog, Tram and Calico Hills.

Other calculations using average properties of the Grouse Canyon Tuff in G-Tunnel were also made to compare the performance at excavation of the various units to that of a geological unit of known performance.

Problems, Limitations, Deficiencies

General Comments — The conclusions are drawn from an extremely limited data base and from a simplified model of mechanical behavior. No justification is given for using the ubiquitous joint model. Few details of the model are given in the document. Details are presumably contained in Johnson and Thomas (1983) and Thomas (1980). Hence, detailed evaluation of the validity of the analyses is not entirely possible on the basis of the document itself.

Detailed Comments — The large amount of typographical errors (e.g., ABSTRACT, line 11; p. 22, line 4; the title for Table 5, p. 19; etc.) and internal inconsistencies [e.g., σ_t used to denote both rock matrix and joint tensile cutoff (Figs. 7 and 8); σ_c used to denote these same values in Table 5] indicate that this report may have been hastily prepared and/or reviewed in order to have it published by the time the SCP was available.

The last paragraph on p. 1 indicates that "material properties were determined through empirical relationships which related the porosity to the desired set of material properties." It should be noted that this relation was not used for all properties. For example, it probably was not used to obtain the transition stress (p. 22) used in the rock matrix failure criterion or for any of the joint properties.

The document repeatedly refers to "limit case" or "lower bound" calculations with the implication that a worst-case set of parameters have been used—yet the joint friction coefficient (0.8) and tension cutoff (0.1 MPa) are the same for both the "limit" case and the "average" case (Table 5, p. 22).

Assuming a water boiling point of 100°C (p. 3) implies ambient pressure conditions.

Several assumptions in the thermal portion of the analyses are questionable. For example, it is not clear that:

(1) the increased heat of vaporization (p. 5) is a conservative assumption for the limit case, as this assumption allows more energy to be removed from the system (Note: On pp. 10-11, it appears that the authors recognize that the assumption is not necessarily conservative.);

(2) the spike in heat capacity shown in Fig. 3 is a good assumption, as it implies that the moisture content is not a function of time but of temperature only; or

(3) conduction is a good approximation to radiation (p. 9) [Note: See Recommendations.].

The choice of the transition stress as being equal to 33.5 MPa (p. 22) for all units and all confining stresses is not obvious—particularly given the heavy reliance, elsewhere, on empirical relations with porosity.

The thermomechanical evaluation of excavation stability uses a ubiquitous joint model to represent vertical jointing in the rock, mass. The results are somewhat confusing and, at a cursory inspection, do not appear to be correct. For example, Fig. 15 does not indicate an extensive region of joint separation at mid-height of the excavation wall. The presence of the excavation will cause a reduction of horizontal stresses near the wall, and thermal loading will produce an increase in vertical stress in the wall. Thus, a large region of joint opening into the excavation could be expected.

The pattern of joint "conditions" in Fig. 15 is strange, particularly considering that a continuum-based code is being used.

The use of the term "joint movement" in the plots is ambiguous. All joints experience relative movement in response to a perturbation. Do the plots only show areas of slip?

The document does not detail how, or if, fractures generated by matrix failure propagate or interact with the ubiquitous joints. The statement (on p. 42, 2nd paragraph) that "no attempt is made to account for motion inhibition effects of intersecting joints and the subsequent interferences that would be expected with the blocky nature of the rock mass" is curious. In many real cases, joints intersect to isolate rock blocks and permit release into an excavation.

Recommendations

No evidence is available to suggest that Topopah Spring is not the preferred target horizon at Yucca Mountain. It is recommended that NRC reviewers of documents referencing this one be made aware of the severe simplifications and limited data base underlying the analyses.

NRC should consider reviewing the report by St. John (1987), which describes recent reference thermal and thermomechanical analyses of drifts for both vertical and horizontal emplacement options at Yucca Mountain.

NRC should consider performing independent thermal and thermomechanical calculations using the material models in both this document and St. John (1987). The calculations should use the Reference Information Base.

NRC should consider reviewing Gartling et al. (1981), cited in the section on "Radiation Approximation" (p. 9) to evaluate whether thermal conduction with high diffusivity is a satisfactory approximation for radiation.

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