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U.S. Department of Energy  
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SUBJECT: TOPICAL REPORT, "PRECLOSURE SEISMIC DESIGN METHODOLOGY FOR A  
GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, REV. 1"

Dear Dr. Brocoum:

The U.S. Department of Energy (DOE) submitted the REV. 0 version of the subject topical report for review by the U.S. Nuclear Regulatory Commission on October 31, 1995. After a detailed staff review and two Appendix 7 meetings with DOE (on March 13-14, 1996, in Las Vegas and on April 23, 1996, in San Antonio), NRC transmitted a set of comments and recommendations on the topical report (refer to NRC letter from Bell, to Brocoum dated May 21, 1996). After considering the staff recommendations, DOE produced the REV. 1 version of the subject report and submitted it for staff review, along with your letter of October 25, 1996. The letter provided a comment-by-comment analysis and DOE's responses to staff's recommendations.

The staff reviewed the DOE responses and the revised version of the topical report. While the staff found the revised version to be a significant improvement, it identified a number of items needing clarification. The staff discussed these points with DOE during an Appendix 7 meeting held at NRC on February 27, 1997. Talking points prepared by the staff were provided to DOE and the affected parties in advance of the meeting in order to focus the discussions and to achieve clarification. The summary of items discussed during the Appendix 7 meeting is enclosed with this letter for DOE's use.

Based on the discussions during the meeting, it is the staff's understanding that appropriate revisions to the topical report will be made by DOE and provided to NRC. As stated in our previous related correspondence and reiterated during the Appendix 7 meetings, the staff decision on the 'acceptability' of the seismic design methodology will be made after the following: (a) final review of the revised seismic Topical Report-II to confirm that changes discussed during the Appendix 7 meeting are indeed incorporated; (b) a detailed review of DOE's third (and final) seismic topical report in the series; and (c) a quick combined review of the three topical reports to ensure that the topical report series covers all important issues related to seismic hazard assessment, design methodology, and design inputs.

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If you have any questions on the contents of this letter or its enclosure, please feel free to contact Dr. Mysore Nataraja of my staff at (301) 415-6695.

Sincerely, ORIGINAL SIGNED BY  
MICHAEL J. BELL

Michael J. Bell, Chief  
Engineering and Geosciences Branch  
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and Safeguards

Enclosure: As stated

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**ENCLOSURE**

## SUMMARY OF NRC/DOE APPENDIX-7 MEETING

on

### TOPICAL REPORT "PRECLOSURE SEISMIC DESIGN METHODOLOGY FOR A GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN (REV. 1)"

The following points were raised and discussed during the Appendix 7 meeting held at the U.S. Nuclear Regulatory Commission Headquarters on February 27, 1997, and clarifications were provided by NRC staff, and specific recommendations were made for the revision of the topical report on seismic design methodology (hereafter referred to as TR-II). The following format is used here under each chapter: (a) a reference to the text is cited, (b) a concern arising from a certain section of the topical report is briefly stated, (c) a brief discussion related to the concern is given, and (d) specific recommendation(s) is(are) provided.

#### EXECUTIVE SUMMARY

##### Concern #1

**Reference:** First Paragraph, lines 5,6: "...YMP/TR-002-NP...has been accepted by the staff."

**Concern:** The staff has not 'accepted' the first seismic topical report (YMP/TR-002, also referred to as TR-I).

**Discussion:** Refer to NRC letter describing the Issue Resolution Status on Seismic TR-I (Bell to Brocoum letter dated July 25, 1996). It is stated in the letter, "...the staff has no further questions at this time on TR-I." TR-I cannot be considered an acceptable reference to the License Application until the staff reviews all three parts of the seismic topical reports and prepares a Safety Evaluation Report (or a Prelicensing Evaluation Report).

**Recommendation:** Make appropriate word changes in this section and in other appropriate sections (for example, in Summary Section 6.1, first paragraph).

##### Concern #2

**Reference:** Last paragraph, Lines 8, 9, 10 and 11: "...it is likely that waste packages will also be determined to be QA classification 1, important to radiological safety...." (Same statement appears again under Section 6.6, third paragraph.)

**Concern:** The language is inconsistent and ambiguous.

**Discussion:** It is not clear whether waste packages will be important to radiological safety or not. The text in Chapter 5 (Waste Package Design) suggests that one of the key performance requirements is preclosure

radiological protection (Section 5.1), thereby implying that the waste packages are important to safety.

**Recommendation:** Either: (a) state that waste packages are important to radiological safety in all sections of the topical report, or (b) avoid such ambiguous language that results in misconceptions or leaves wrong perceptions in readers' minds.

## 1.0 INTRODUCTION

### Concern #1

**Reference:** Figure 1-1.

**Concern:** Although this figure is an improvement from Rev. 0, it still does not show all the links and potential interactions between steps.

**Discussion:** Links between step-1 and step 3 and back and forth interaction between step 2 and step 3 are possible.

**Recommendation:** Further examine the links between step 1 (TR-I) and step 3 (TR-III) and any possible two-way interactions [for example, between step 2 (TR-II) and step 3 (TR-III)] and revise the figure appropriately.

### Concern #2

**Reference:** Section 1.4, Assumptions, Line 6: "Consistent with...maintainable service life of 150 years following first emplacement of waste...."

**Concern:** It is not clear what the actual design assumption is with respect to design life. It is also somewhat ambiguous whether the drifts will be maintenance-free.

**Discussion:**

- (a) The acceptance criteria being adapted are based on a service life of 50 years (UBC) or less (nuclear power plants). How does one extrapolate the design to 150 years? Are there any implications to the design methodology?
- (b) Some of the recent changes to repository design suggest that the emplacement drifts may be lined with precast concrete rings to achieve a 'maintenance-free' service life of 150 years. If this is the case, it is not consistent with the key assumption that the life is a 'maintainable service life' (which means it is not maintenance-free).
- (c) DOE Design presentations on different occasions and certain design documents have used 50, 100, and 150 years as design life for the repository. This makes it unclear as to what is the actual assumption

with respect to design life. (Another minor point is that if the service life is expected to be 150 years following the first emplacement of waste, then the expected life could be more than 150 years for many emplacement drifts.)

**Recommendation:** Clarify the actual design assumption and make it consistent with other design documents. Also, discuss the impacts of design life and maintenance issues on the seismic design methodology proposed in the topical report.

## **2.0 REGULATORY PERSPECTIVE**

### **Concern #1**

**Reference:** Reference to the 'proposed rulemaking' (60 FR 15180) for 10 CFR Part 60, with respect to the design basis events (DBE), in Section 2 and other parts of the topical report.

**Concern:** The reference does not reflect the current status of rulemaking.

**Discussion:** When the topical report was written, the rulemaking was still under review, however, it is final now and should be referenced as such.

**Recommendation:** Revise the topical report appropriately in this section and the Summary Section 6.3 and many other sections where the rule is referred to.

### **Concern #2**

**Reference:** Section 2.3.2, NRC Policy Statement on Probabilistic Risk Assessment (PRA).

**Concern:** The contents of this section appear to be more appropriate for the topical report concerning hazard rather than this topical report dealing with design methodology.

**Discussion:** The design methodology is not affected by how the design earthquake was arrived at, whether by using PRA or otherwise.

**Recommendation:** Consider removing the section or clarifying how this policy statement affects the design methodology.

### 3.0 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS (SSC) FOR VIBRATORY GROUND MOTION

#### Concern #1

Reference: Sections 3.1.1 and 3.1.2.

**Concern:** The rationales used to justify the reference mean annual exceedance probabilities under these two sections seem to create unnecessary confusion.

#### **Discussion:**

- (a) The reference to 1.0E-02 for Frequency-Category-1 is unwarranted. The staff considers the suggestion that a 100-year earthquake is acceptable as a DBE is unjustified. The staff believes that this reference is unnecessary and prefers the approach used in Section 3.1.2. It recommends the same kind of language and approach be adopted for Section 3.1.1.
- (b) DOE considers the probability, which corresponds to a 1000-year return period, represents an extremely conservative quantitative translation. Although the staff considers that a 1000-year return period is an adequate design basis for the Frequency-Category-1 SSCs, the staff cannot endorse the idea that it is 'extremely conservative' for the following reasons: (i) UBC requires a 500-year earthquake as a design basis for a 50-year life of the structure (90 percent chance of not being exceeded in 50 years), therefore, a 1000-year event could be considered conservative for a structure with a 50-year life; (ii) based on this logic, the DBE chosen by DOE (i.e., the 1000-year event) would be considered adequate but not 'extremely conservative' for a structure with a 100-year life; (iii) if, however, the design life is 150 years, then the corresponding DBE would be a 1500-year event, and, hence, the 1000-year event chosen by DOE would not even be consistent with the UBC requirement.

**Recommendation:** Clarify the assumptions on design life and provide proper rationale for Frequency-Category-1 events using a logic similar to that used for Frequency-Category-2 events.

#### Concern #2

Reference: Section 3.1.2.1, page 3-3, second paragraph, last sentence, refers to DG-1032: "...this analysis used for reference the probability of exceeding the average of the 5 and 10 Hz safe shutdown earthquake response spectrum ordinates."

**Concern:** It is not clear whether the frequency range quoted above (5-10 Hz) would be representative of the SSCs in a repository.

**Discussion:** Is there a tacit assumption that the SSCs under consideration will exhibit similar frequencies in comparison to those in a reactor facility? Is this an important factor affecting the design methodology and acceptance criteria?

**Recommendation:** Clarify as to whether this frequency range covers the SSCs in the repository surface facilities.

### Concern #3

**Reference:** Section 3.1.2.2, page 3-4, second bullet.

**Concern:** The information in this paragraph contains some points that need clarification, as discussed below.

**Discussion:**

(a) The conclusion that a plant designed to 0.25g has a margin above 0.3g is not very convincing; (b) Arizona Public Service Company (APS) elected to perform a margins analysis--it was not required by NRC, as stated in TR-II; and (c) in addition, NRC accepted a request from APS to have its review level earthquake lowered from 0.5g to 0.3g.

**Recommendation:** The following language is suggested: In the middle of this second bullet on page 3-4, use the following two sentences: "Given the relatively low seismic hazard, APS successfully persuaded the NRC staff to have its review level earthquake reduced from the 0.5g in NRC 1991b to 0.3g. APS elected to conduct a seismic margins analysis for the IPEEE program, rather than a seismic risk assessment. The margins...."

### Concern #4

**Reference:** Section 3.2 Design of Surface Facilities, first paragraph, third sentence, "NUREG-0800, in general, describes...."

**Concern:** The statement does not characterize the NUREG properly.

**Discussion:** NRC uses a standard language to describe the function of NUREG-0800.

**Recommendation:** To properly characterize NUREG-0800, the following is suggested: "NUREG-0800, in general, assures the quality and uniformity of NRC staff review and in some cases complements regulatory guides by providing a basis acceptable to the staff that may be used to implement requirements in the Commission's regulations."

#### Concern #5

**Reference:** Section 3.2, page 3-6, sixth bullet.

**Concern:** The item under this bullet is unnecessary as this issue has been addressed in the latest version of the review plan.

**Discussion:** See 1989 revision in which the SRP states: "The control motion should be defined on a free ground surface and should be based on data obtained in the free field." The SRP Sections 3.7.2 and 3.7.3 were also revised in August 1989.

**Recommendation:** Delete this item.

#### Concern #6

**Reference:** Use of NUREG-0800 SRP Sections for seismic design (general).

**Concern:** TR-II does not reflect an understanding of the NRC policy on SSE/OBE designs and how the policy might impact on the repository design.

**Discussion:** TR-II needs to reflect the understanding that the SRPs refer to design procedures which involve two levels of earthquakes, namely the OBE and the SSE for nuclear power plants. However, there will be only one level of earthquake for the repository SSCIS, either the 1000-year or the 10,000-year earthquake, depending on the frequency category. Staff guidance on how to deal with a design consisting of a single earthquake is contained in SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs."

**Recommendation:** Include discussions related to this important design issue in TR-II. DOE should commit to following the applicable guidance provided in SECY-93-087 or identifying the alternative procedures for staff review and comment.

#### Concern #7

**Reference:** Partial/complete applicability of design SRPs (general).

**Concern:** TR-II does not discuss the complete or partial applicability of other design SRPs contained in NUREG-0800 (for example, 3.8, 3.9) and other codes and standards, such as ACI, AISC, etc. Nor is there a discussion of the applicability of design methods, such as elastic/inelastic, working stress or ultimate stress, etc.

**Discussion:** The staff will have difficulty in evaluating the DOE design methodology in the total absence of reference to design guides. The scope of TR-II has been limited by DOE to design loads only, and the acceptance criteria for designs themselves can be found in SRP Sections not mentioned in the topical report.

**Recommendation:** It is recommended that a subsection be added under Section 3.2, which briefly describes the above information that may be unique to seismic design of the repository. The staff realizes that these topics are common to several aspects of the repository design and, therefore, an exhaustive treatment is not required within TR-II.

**Concern #8**

**Reference:** Section 3.3.1, page 3-7, end of first continuing paragraph, last sentence.

**Concern:** The statement related to the proposed rulemaking, which implies that a new design requirement has been added, is incorrect.

**Discussion:** To the best of staff's knowledge, no new design requirement related to underground facility was added. The requirement being cited already existed under 10 CFR 60.133.

**Recommendation:** The statement in question needs to be either removed or clarified.

**Concern #9**

**Reference:** Section 3.3.2.2, second paragraph, fourth item.

**Concern:** Impracticality of inspection and maintenance of waste emplacement drifts.

**Discussion:** One of the arguments being made by DOE to address the issue of repetitive seismic loading, is to propose inspection and maintenance in the drifts after a seismic episode. While this may be possible and acceptable for the main drift, the ventilation drift, and other operational drifts/ramps, it will be extremely hazardous in waste emplacement drifts.

**Recommendation:** References should be provided to design reports that describe how inspection and maintenance will be done in the presence of emplaced wastes.

**Concern #10**

**Reference:** The issue of threshold damage criterion (general).

**Concern:** There is a general concern and an overall observation on this section regarding a lack of appropriate analyses.

**Discussion:** The staff prefers to see some appropriate analyses to show that the SSCs would withstand combined effects of excavation-induced, in-situ, thermal, and seismically-induced stresses (including the incremental effects of repetitive loads). The 200 mm/sec velocity criterion used by DOE as a

threshold for damage represents average conditions for many underground facilities in several different rock types and, therefore, is a good starting point. However, the staff observes that reference to detailed analyses that take into account the actual conditions at the Yucca Mountain site, including appropriate design inputs, is missing. For example, the analyses should consider the range of heat loads, the range of joint conditions, opening geometry, in-situ stress combinations, and seismic events and their cumulative effects over the preclosure period. If DOE chooses a maintenance-free underground environment for the emplacement drifts, the design should accommodate the critical combinations of severe conditions. (This is especially important from the point of view of retrievability considerations.) The information presented in this section is mostly qualitative and somewhat speculative and needs to be strengthened.

**Recommendations:** Provide summaries of example analyses along with references to appropriate reports where details can be found.

#### Concern #11

**Reference:** Section 3.3.3.1, page 3-11, last two paragraphs.

**Concern:** Lack of experience in the use of stress reduction factor.

**Discussion:** Some explanation is necessary as to how, without any past experience, the stress reduction factor can be extended to seismic and thermal stresses. Also, it is not clear how the empirical design charts, such as Figure 3-2, provide insights into identification of potential failure mechanisms.

**Recommendation:** Expand the section to cover the above two points.

#### Concern #12

**Reference:** Section 3.3.3.2, Dynamic Approach, page 3-18.

**Concern:** Unrealistic/nonrepresentative example.

**Discussion:** The example calculation presented has an input motion of 1 to 3 seconds that appears to be very unrealistic and non-representative.

**Recommendation:** Perhaps a better representative example could be provided, using time histories of motion similar to those that can be expected at Yucca Mountain.

**Concern #13**

**Reference:** Section 3.3.4, Acceptance Criteria.

**Concern:** The discussions provided on the selection of appropriate factors of safety are somewhat vague.

**Discussion:** In the staff's view, minimum acceptable factors of safety need to be proposed in TR-II. Right now, there is no commitment on the part of DOE as to what is an acceptable factor of safety for a given method of underground facility design.

**Recommendation:** Expand the section to include expected performance and suggested acceptable factors of safety.

**Concern #14**

**Reference:** Page 3-21.

**Concern:** Missing details.

**Discussion:** Figure title and number are missing.

**Recommendation:** Provide missing details.

**4.0 DESIGN OF REPOSITORY SSCs FOR FAULT DISPLACEMENT**

**Concern #1**

**Reference:** Section 4.2.1, page 4-2, end of first continuing paragraph.

**Concern:** Results of simplified analysis cited may be misleading.

**Discussion:** The simplified analysis performed by SNL uses 0.4g and concludes that, "These results show that well-designed SSCs conservatively can withstand small fault displacements without loss of function." This summary needs to be put in the proper perspective. The horizontal ground surface acceleration of 0.4g is not representative for Frequency-Category-2 events. Also, 'small' fault displacements are not of concern.

**Recommendation:** Clarify whether the discussion is applicable to both surface and underground facilities. Also, clarify the significance of the examples cited (use 0.4g acceleration) in the context of repository design at Yucca Mountain.

**Concern #2**

**Reference:** Section 4.2.1, last paragraph.

**Concern:** Applicability of simplified analyses performed by Kennedy, et al.

**Discussion:** Analyses performed by Kennedy, et al., are for dense cohesionless soil and their applicability to the Yucca Mountain site conditions need to be qualified.

**Recommendation:** Discuss the applicability and limitations of using the results of the above simplified analyses to the Yucca Mountain project.

**Concern #3**

**Reference:** Section 4.4.1, Criteria for Fault Avoidance, page 4-4.

**Concern:** Lack of discussions on threshold values of strains, stand-off distances, etc.

**Discussion:** Even though it is difficult to discuss strains/displacements and stand-off distances, etc., without specific references to structures, systems and components, some quantitative descriptions could be provided regarding the threshold values and factors of safety associated with them.

**Recommendation:** Provide quantitative descriptions as appropriate, or provide reference to where such descriptions can be found.

**Concern #4**

**Reference:** Section 4.4.1, page 4-5.

**Concern:** Vagueness in the probabilistic definition of Type I fault.

**Discussion:** In defining the probabilities, the following expression is used, "...for which there is negligible engineering concern...." This expression is too vague and needs to be defined more explicitly.

**Recommendation:** Discuss how the definition provided in NUREG-1494 is related to the probabilistic definition provided in TR-II.

**Concern #5**

**Reference:** Various discussions related to level of investigations of Type I faults:

**Concern:** A generic concern on level of fault investigations and identification of such details in TR-II.

**Discussion:** A number of Type I faults have been identified in and around the Yucca Mountain Region (CNWRA 96-007). As of June 1996, slip rates and recurrence intervals have been identified for only a small number of Type I faults. TR-II does not identify how many and which particular Type I faults will be investigated in detail. In addition, TR-II does not distinguish between Type I faults that affect seismic and fault displacement inputs to design from those that impact post-closure performance.

**Recommendation:** In the event that all Type I faults are not being characterized in detail, the staff recommends that DOE present in TR-II criteria used for selecting certain Type I faults for detailed investigation.

## **APPENDIX B**

**Reference:** Last paragraph, page B-2:

**Concern:** Isolated description of 'beyond-design-basis events' that is disconnected from the rest of the topical report.

**Discussion:** The discussion related to 'beyond-design-basis events' does not mention anything about how and when will the design process consider such events.

**Recommendation:** The discussion should be expanded to include such considerations. For example, show this step of the design in Figure A-1 and in Chapters 3, 4, and 5.

## **APPENDIX C**

A general observation on Appendix C is that the overall clarity could be improved. Examples were provided during the meeting.