August 4, 2003

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SUBJECT: RESULTS OF THE U.S. NUCLEAR REGULATORY COMMISSION REVIEW OF THE NAVAL NUCLEAR PROPULSION PROGRAM PROBABILITY METHODOLOGY

Background

The Safety Evaluation Report (SER) issued for the Naval Nuclear Propulsion Program (NNPP) Addendum to the Disposal Criticality Analysis Methodology Topical Report (TR) provides the overall U.S. Nuclear Regulatory Commission (NRC) evaluation of the NNPP criticality methodology. However, NRC deferred reviewing the NNPP probability methodology portion of the TR (used to determine the probability of a criticality event involving naval spent nuclear fuel (SNF) occurring in the proposed Yucca Mountain repository) to further evaluate previously unaddressed regulatory issues. This letter documents the results of this review.

It should be noted that while this letter is intentionally unclassified and therefore available to the public, the NNPP documents identified in this letter along with some associated NRC documents are classified and therefore unavailable to the public.

NNPP Event Types

The NNPP probability methodology, primarily documented in Features, Events, and Processes (FEPs) Paper 9 from the NNPP issue resolution process, covers three main event types.

Event Type A: Loading fuel of the wrong type or without poison materials or poison pins into a waste canister,

Event Type B: Using the incorrect materials in spent fuel baskets, poison materials, or poison pins,

Event Type C: Failure of a spent fuel basket with zircaloy support plates prior to emplacement due to a human error.

This letter identifies areas where the NNPP methodology should be revised and enhanced to provide a transparent and defensible basis for evaluating the probability calculation. A more detailed discussion is provided in the attachment.

Event Type A

The NNPP should perform an assessment, including evaluating relevant human actions, sufficient to quantify the potential for a nuclear criticality event. The expected characteristics of this assessment are identified below.

- A quantitative assessment of human failure probabilities consistent with current approaches and methods for human reliability analysis (HRA). Such an assessment should include:

  1. Logic diagrams such as event trees and/or fault trees that clearly depict possible activities and errors that might cause a criticality event. Dependent activities and interfaces need to be identified.

  2. A layout of the receipt and loading operations of the NNPP waste canister at the Expended Core Facility (ECF).

- The HRA should be "realistic," representing processes as they are actually carried out. The existence of procedures and policies alone does not automatically guarantee that activities are performed as formally described.

- Good practice in HRA generally results in failure probabilities of 10^{-4} or 10^{-5} as a lower limit for single processes that include some "independent" checking. Consequently, human failure event probabilities assigned lower failure probabilities must include additional independent checks via separate equipment or processes (e.g., quality assurance processes that include separate personnel, procedures, etc.).

- The HRA should contain justification for the assigned human failure probabilities, including addressing the factors that could influence human performance in the NNPP task environment.

Event Type B

The NNPP should perform an assessment of using incorrect materials that in general presents the information previously provided by the NNPP in an integrated form and with a more transparent technical basis. This includes providing information on the NNPP material quality assurance program.

The assessment should provide a quantitative estimate of the likelihood of the use of incorrect materials. As discussed for Event Type A, the analysis for evaluating the use of incorrect materials should have the following characteristics: (a) a logic model that shows the events that if they occurred could result in the use of incorrect material, (b) a probability estimate of the events, and (c) the basis for the probability estimates. In contrast to Event Type A, less detailed analyses may be needed of activities within a facility since multiple facilities (material vendor, manufacturing vendor, and the expended core facility) are expected to have generally independent programs to control materials.

Additionally, the NNPP should provide a description of the material quality assurance program. This description has two objectives. The first objective is to provide an integral understanding of the material quality assurance program. The second objective is to provide context for the actual tests and inspections included in the assessment.

Event Type C

The NNPP should provide information that supports its view that spent fuel baskets with zircaloy support plates will arrive at the geologic repository and be emplaced intact within an inerted canister. The NNPP should show that the performance of the spent fuel baskets will not be compromised by human errors during manufacturing, loading, or handling, i.e., that the safety factors of the design of the spent fuel basket incorporate the potential for human errors. In contrast to event type A, an HRA may not be necessary to evaluate this event, though a thorough description of the factors incorporated in the assessment of human errors needs to be included, e.g., training, procedures, past practice.

Use of Risk Informed Analyses

The NNPP has previously indicated that it intends to use its probability methodology to determine whether a nuclear criticality event involving naval SNF should be included in the performance assessment. This letter assumes that the NNPP will continue to pursue such an objective. However, evaluating criticality events using both probability and consequences may provide a more defensible technical basis with less overall effort, including less effort by the NRC staff. Preliminary analyses performed by the NRC staff indicate that the effect of a criticality event in a single waste package on repository performance may be limited. These preliminary analyses suggest that a risk calculation may provide additional information useful for evaluating whether a nuclear criticality event involving naval SNF should be included in the performance assessment.

Conclusion

The NRC has reviewed the NNPP methodology to determine the probability of a nuclear criticality with naval SNF in the repository. This letter identifies areas where the NNPP methodology should be revised and enhanced to provide a transparent and defensible basis for evaluating the probability calculation. If you have any questions regarding these matters, please contact Mr. Dennis Galvin of my staff. He can be reached at (301) 415-6256.

Sincerely,

/RA/

Janet Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: As stated
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The NNPP has previously indicated that it intends to use its probability methodology to determine whether a nuclear criticality event involving naval SNF should be included in the performance assessment. This letter assumes that the NNPP will continue to pursue such an objective. However, evaluating criticality events using both probability and consequences may provide a more defensible technical basis with less overall effort, including less effort by the NRC staff. Preliminary analyses performed by the NRC staff indicate that the effect of a criticality event in a single waste package on repository performance may be limited. These preliminary analyses suggest that a risk calculation may provide additional information useful for evaluating whether a nuclear criticality event involving naval SNF should be included in the performance assessment.

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Detailed Comments on the Naval Nuclear Propulsion Program (NNPP) Probability Methodology

This attachment provides further information on areas where the NNPP methodology should be revised and enhanced to provide a transparent and defensible basis for evaluating the probability calculation. The three event types and the guidance in the cover letter is repeated in the attachment in italics to provide a clear link between the cover letter and the attachment.

NNPP Event Types

The NNPP probability methodology, primarily documented in FEP paper 9 from the NNPP issue resolution process, covers three main event types.

Event Type A: *Loading fuel of the wrong type or without poison materials or poison pins into a waste canister,*

Event Type B: *Using the incorrect materials in spent fuel baskets, poison materials, or poison pins,*

Event Type C: *Failure of a spent fuel basket with zircaloy support plates prior to emplacement due to a human error.*

Comment

NNPP FEP paper 9 also addresses other event types, but these are not directly involved in the NNPP probability methodology, so discussion of the other event types is beyond the scope of the letter and attachment.

Event Type A: **Loading fuel of the wrong type or without poison materials or poison pins into a waste canister**

The NNPP should perform an assessment, including evaluating relevant human actions, sufficient to quantify the potential for a nuclear criticality event. The expected characteristics of this assessment are identified below.

- *A quantitative assessment of human failure probabilities consistent with current approaches and methods for human reliability analysis (HRA). Such an assessment should include:*

Comment

> One current approach that was considered during the review of the NNPP probability methodology involved the use of ASME RA-S-2002, “Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications.” This ASME standard includes guidance for performing an HRA. The NRC has not adopted this standard and has identified several clarifications and qualifications regarding ASME RA-S-2002 in Draft Regulatory Guide DG-1122, “An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities.”

1. *Logic diagrams such as event trees and/or fault trees that clearly depict possible activities and errors that might cause a criticality event. Dependent activities and interfaces need to be identified.*

Comment

The HRA should avoid unsupported decomposition of processes for human failure probability quantification. Past HRA reviews have shown that such unnecessary decomposition can produce unrealistic and noncredible results, e.g., the decomposition of a process into five seemingly independent activities.

2. *A layout of the receipt and loading operations of the NNPP waste canister at the Expended Core Facility (ECF).*

Comment

The layout should identify where activities associated with the receipt and loading operations may occur along with any concurrent unrelated operations that may affect the receipt and loading operations.

- *The HRA should be "realistic," representing processes as they are actually planned to be carried out. The existence of procedures and policies alone does not automatically guarantee that activities are performed as formally described.*

Comment

For example, the required timing of personnel response to off-normal conditions may be so short as to prevent the formal use of procedures.

- *Good practice in HRA generally results in failure probabilities of 10^{-4} or 10^{-5} as a lower limit for single processes that include some "independent" checking. Consequently, human failure event probabilities assigned lower failure probabilities must include additional independent checks via separate equipment or processes (e.g., quality assurance processes that include separate personnel, procedures, etc.).*

- *The HRA should contain justification for the assigned human failure probabilities, including addressing the factors that could influence human performance in the NNPP task environment.*

Comment

a. Examples of factors/questions that might be considered in the initial misloading failure are:

- What are the possible sources of distractions (e.g., other activities being performed nearby; unusual activities, such as unexpected loud noises, medical emergencies) to personnel performing loading tasks? How frequent are such distractions?

- What means do personnel have for re-starting their task in the correct spot after being distracted?

    - How isolated is the task performance area from other activities? How could these other activities negatively impact the task performance area (e.g., could someone place a load of material in front of poisons to be loaded, blocking personnel view of the poisons?)?

    - What aids do personnel have for remembering to do self-checking? How might these checks be influenced by distractions?

    - What aids do personnel have for remembering to check each other? How might these checks be influenced by distractions?

    - How repetitive are the actions that are being performed? (Highly repetitive tasks are especially prone to failures in attention, e.g., omissions associated with interruptions.)

    - Are there other factors that might limit the amount of time or attention given to the loading process (e.g., high priority given to certain "production" goals – 2 waste canisters loaded per day, regardless of unexpected delays to process (like broken equipment); transportation of canisters is available only once a day and at specific times, creating an urgency to complete all tasks in time to make "load time")?

b. Examples of factors/questions that might be considered in the failure of a quality assurance process to detect an initial misloading failure are:

- Are personnel performing the quality assurance task completely separate and independent of the personnel (including supervisors) performing loading tasks?

- Does the quality assurance check include physical examination of the waste canister (i.e., not simply a verification of appropriate paperwork)? Does the quality assurance check include a thorough inspection of the work area (including looking for material that might be "hidden" by material or activities of adjacent tasks?

- What aids do quality assurance personnel have for remembering to perform each aspect (especially physical checks) of an independent verification? How might these verifications be influenced by distractions?

- If quality assurance personnel have other duties, what priority is given to verification of poison loading? Can workload influence the quality assurance task (e.g., limited time available for poison loading verification so "shortcuts" are used, such as eliminating certain checks)?

- Are there other factors that might limit the amount of time or attention given to the quality assurance process (e.g., high priority given to certain "production" goals, such as 2 waste canisters loaded per day, regardless of unexpected delays to process (like broken equipment); transportation of canisters is

available only once a day and at specific times, creating an urgency to complete all tasks in time to make load time)?

c. The results of the exercises discussed in (a) and (b) could be considered a partial task analysis.

d. To the extent practical, the NNPP should use available relevant data either in preparing the HRA or in evaluating the reasonableness of the results.

- The NRC staff recognizes that data may not be available to directly estimate the likelihood of a misload for the entire NNPP canister loading process. However, the NNPP may be able to compile data that is applicable to individual steps of the canister loading process, either as a basis for a likelihood estimate or to confirm an estimate from an HRA. The NRC staff notes that fuel handlers at the ECF are required to notify their supervision whenever a fuel assembly is not in compliance with material control data. If this and similar events were documented by the NNPP, likelihood estimates could be made to augment estimates made in the HRA.

- The NNPP should also consider using data recently compiled by the Office of Civilian Radioactive Waste Management (OCRWM). The OCRWM report, "Waste Package Misload Probability," CAL-WHS-MD-000001 Rev. 0, provides some data on nuclear fuel misload and damage events. This report is a compilation of Licensee Event Reports (LERs) and other commercial industry data that involve fuel assembly misloads in reactors and spent fuel pools, fuel assembly damage, and errors in fuel rod loading. While the NRC has not performed a detailed review of the OCRWM report and its references, which would be necessary to gain a clear understanding of the data and its applicability, the OCRWM report does provide some useful information on the causes of events and the likelihood of events.

- The OCRWM report briefly describes the cause for each fuel assembly event, many of which may be applicable to NNPP fuel handling operations. The causes as described involve conditions that may affect any operation reliant on human action: (a) inattention to detail; (b) mis-communication among workers; (c) misreading identification numbers; (d) worker overconfidence; (e) poor understanding of requirements; (f) operator inexperience; (g) mis-fabrication of components; (h) inadequate procedures; (i) inadequate verification of either self or others; (j) inadequate safety analysis; and (k) failure to follow procedures. Since these causes are taken from actual events, they may be considered credible and a reasonable starting point for the initial analysis of fuel handling operations.

- The OCRWM report also includes the calculation of the likelihood of a fuel assembly misload. This calculation indicates that excluding fuel assembly misloads from a nuclear criticality assessment may be inappropriate based on the fuel assembly misload likelihood alone. While the applicability of calculated likelihood to naval SNF is open to interpretation, the NNPP should not dismiss the calculation on this basis alone or because it is associated with commercial reactor facilities. As the NRC staff will consider the available fuel handling data (the OCRWM report is the main source identified to date) in evaluating

reasonableness of any NNPP analysis, the NNPP should also consider the available fuel handling data, at least to determine whether it is applicable to NNPP operations.

A photograph or digital image that demonstrates that the loading process was completed correctly may reduce the scope of a potential probabilistic assessment.

The NNPP should consider using photographs or digital images to create permanent records of the loaded configurations. The NNPP current plans include having independent qualified operators make visual inspections at various steps of the loading process. Photographs or digital images taken at the appropriate steps in the loading process, which capture uniquely identifying information for the loaded components (the components covered by Event Type A), may provide the NNPP with a substantial record that demonstrates that the fuel canisters were loaded as designed. Such records may significantly reduce the scope of a potential probabilistic assessment.

***Event Type B:* Using the incorrect materials in spent fuel baskets, poison materials, or poison pins**

The NNPP should perform an assessment of using incorrect materials that in general presents the information previously provided by the NNPP in an integrated form and with a more transparent technical basis. This includes providing information on the NNPP material quality assurance program.

The assessment should provide a quantitative estimate of the likelihood of the use of incorrect materials. As discussed for Event Type A, the analysis for evaluating the use of incorrect materials should have the following characteristics: (a) a logic model that shows the events that if they occurred could result in the use of incorrect material, (b) a probability estimate of the events, and (c) the basis for the probability estimates. In contrast to Event Type A, less detailed analyses may be needed of activities within a facility since multiple facilities (material vendor, manufacturing vendor, and the expended core facility) are expected to have generally independent programs to control materials.

Comment

- In general, the information provided by the NNPP indicates that the incorrect use of material in zircaloy and hafnium components has an extremely low likelihood. This initial assessment is based upon the understanding of (a) the rigorous procurement and material controls and tests in place at the material vendor, (b) the material controls including alloy identification for 100% of the zircaloy and hafnium components in place at the manufacturing vendor, and (c) the material controls including alloy identification for 100% of the zircaloy and hafnium components in place at the expended core facility. The revised methodology should provide a more transparent and defensible technical basis.

- The NNPP should provide an integrated analysis of the use of incorrect materials in the construction of baskets, poison materials, or poison pins. While the type and level of detail of events discussed in information already provided by NNPP appears adequate, the information in its current form is difficult to review and is spread through several analyses (due in part to the nature of the issue resolution process). While some information may need to be left in its present form, such as information that addresses

individual FEPs, a single integrated analysis that addresses the control of the identified materials is needed. The several documents or sections of documents that the NRC staff reviewed in its initial assessment of material control issue are listed along with the information the NRC staff found useful and that should be considered for inclusion in a revised analysis.

- FEP Paper 9, Section V (pages C.3-256 to C.3-257), presents a general list of tests that would be performed on zircaloy and hafnium components.

- FEP Paper 9, Section VI (pages C.3-258 to C.3-259), describes how the NNPP proposed to meet the probability criterion. The discussion is similar to the previous bullet, though with less detail.

- FEP Paper 10, Process 4 (pages C.3-288 to C.3-290), provides a more detailed though somewhat general description in tabular form of how material will be controlled from procurement to installation.

- FEP Paper 10, Process Description 2 (pages C.3-295 to C.3-297), provides a more detailed though still somewhat general description in narrative form of how material will be controlled from procurement to installation. Standards MIL-STD-2132 and ASTM 1476 are identified.

- FEP Paper 10, Process Error Summaries for zircaloy and hafnium materials (pages C.3-306 to C.3-307), provides a list of controls in place to prevent the use of incorrect materials. This list references FEP 10, process 4, with a comparable level of detail.

- FEP Paper 1, FEPs 8 (pages C.3-25 to C.3-29), 19b (pages C.3-39 to C.3-41) and 23 (pages C.3-42 to C.3-44), provides a preliminary list of tests and inspections that will be performed on the zircaloy and hafnium components along with the standards and specifications the tests and inspections will be performed against. The FEP papers identify where 100% inspections will be performed. FEP paper 8 also describes why allowable variations in zircaloy elements will not affect zircaloy corrosion performance and a discussion on the NNPP interpretation of 100% inspection.

- Appendix D, Original Addendum Sections D.2.3.1 (pages D-3 to D-4) D.4.1 (pages D-7 to D-8) and D.4.5 (pages D-13 to D-14), provides the NNPP's initial calculations for the probability of using incorrect materials. A similar level of detail in a revised analysis with the characteristics identified in this letter may provide a reasonable basis for determining the probability of the use of incorrect materials.

- The NNPP should provide a clear technical basis for its model of a chemical composition test. In its original analyses, the NNPP models a chemical composition test as an independent test and five independent checks because the material being characterized has six major elements. Generally partial if not complete dependence is assigned to multiple tests or checks, both for the performance and interpretation of the tests. The NNPP needs to provide a clear technical basis for a model involving multiple independent tests.

Additionally, the NNPP should provide a description of the material quality assurance program. This description has two objectives. The first objective is to provide an integral understanding of the material quality assurance program. The second objective is to provide context for the actual tests and inspections included in the assessment

<u>Comment</u>

- The NNPP should clearly identify the test standards, inspections, or specifications that will be used. Sufficient information about the tests or inspections should be provided to support the estimated values in the probabilistic assessment.

<u>Event Type C:</u> **<u>Failure of a spent fuel basket with zircaloy support plates prior to emplacement due to a human error</u>**

The NNPP should provide information that supports its view that spent fuel baskets with zircaloy support plates will arrive at the geologic repository and be emplaced intact within an inerted canister. The NNPP should show that the performance of the spent fuel baskets will not be compromised by human errors during manufacturing, loading, or handling; i.e., that the safety factors of the design of the spent fuel basket incorporate the potential for human errors. In contrast to event type A, an HRA may not be necessary to evaluate this event, though a thorough description of the factors incorporated in the assessment of human errors needs to be included, e.g., training, procedures, past practice.

<u>Comment</u>

- Under a risk informed licensing basis, not only should the mechanical design of the basket be evaluated with respect to design basis loads, but the design of the basket should also be evaluated for susceptibility to human errors. While the current basket design does appear to have a low susceptibility to human errors, a final determination can only be made once an actual design, including the manufacturing and fuel loading processes, has been decided upon. While the NNPP has identified that the basket will be manufactured in accordance with ASME standards and will be subjected to a proof test specific details are needed as discussed below.

- Demonstrate that spent fuel baskets with zircaloy support plates will arrive at the geologic repository and be emplaced intact within an inerted canister. The NNPP should describe the codes and standards that will be used in this demonstration. The demonstration should also include the load design basis and the safety factor design basis.

- Show that the performance of the baskets will not be significantly affected by potential human errors in the manufacturing or loading process. The analysis should identify and evaluate potential human errors that could provide those conditions, if any, that may lead to the failure of the basket. In this regard, the procedure to inert the canister seems particularly important. A probabilistic approach may not be needed if the bounding conditions potentially experienced by the basket are within the design basis. As an alternative method, the NNPP should show that procedures and processes accepted for transportation and storage (see NUREG-1617 and NUREG-1536) are applicable to Part 63.

- The NNPP may evaluate this FEP solely from geometric considerations if applicable. Depending on the design of the spent fuel basket with zircaloy support plates, it may not matter if certain components fail from a geometry control perspective. That is, if there is not room within a sealed waste canister for zircaloy support plates to move and no longer provide geometry control, then it may not matter if components that hold the basket together fail. Therefore, the NNPP may provide a geometric analysis of the spent fuel basket and waste canister if applicable and take a graded approach on the other analyses.