AREVA

MAP Series of PWR Fuel Assembly Packages

AREVA NP Inc

NRC Meeting – September 24, 2007

Richard Montgomery
Robert Freeman
Charlie Sanders
Chuck Temus
Greg Banken

Meeting Objectives

- **Review NRC questions**
  - **Thermal, Containment, Criticality, General Description, Structural**
- **Discuss AREVA response to NRC question**
- **Determine acceptability or need for further clarification**

Response to NRC Questions

- **AREVA to formally respond to NRC question**
- **AREVA to provide page changes to SAR**

Review Questions

- **NRC Question 3-1**
  - **Revise the following pages to incorporate omitted references: 3-16, 3-25, 3-46, 3-47, 3-48.**
- **AREVA proposed response**
  - **The identified pages will be revised to indicate the correct references as indicated below:**
    - **Page 3-16 – Figure 3-1**
    - **Page 3-25, first instance – Figures 2.12.1-62 through 2.12.1-65 and Table 2.12.1-4.**
    - **Page 3-25, second instance – Figures 2.12.1-69 and 2.12.1-70.**
    - **Page 3-46 – Figure 3-22.**
    - **Page 3-47 – Figure 3-22.**
    - **Page 3-48, first instance – Delete text, no further reference needed.**
    - **Page 3-48, second instance – Delete text, no further reference needed.**

Review Questions

NRC Question 3-2

- **Provide a figure that reports steady-state temperatures for the MAP-12/MAP-13 packages under NCT hot conditions with insolation. Justify that the method used to apply solar insolation (assuming a diurnal cycle as opposed to a constant heat flux) provides a conservative result.**
- **Figure 3-1 of the SAR shows the time evolution of NCT temperatures under hot conditions with solar insolation. It is not clear from the figure that the package reaches steady state temperatures for the time scale presented..**

AREVA proposed response

- **Diurnal cycle provides 10 CFR 71.71 (c)(1) specified insolation over 12 hour period. IAEA Safety Guide TS-G-1.1 (654.4), time dependant sinusoidal heat flux is more precise - model insolation.**
- **Peak and average foam temperatures achieved with the diurnal cycle are 201 and 144°F, respectively, versus 174 and 142°F, respectively, for steady-state analysis using 24-hour average solar. Two methodologies provide essentially same average foam temp. Diurnal cycle yields higher peak foam temperature and higher thermal gradient.**
- **Change in component temperatures over last 24 hours of the 10 day heat-up period depicted in Figure 3-1 is 0.5°F, or less – indicating steady-state conditions are essentially attained. <u>An enlarged plot of the transient heat up plus a figure depicting the alternative steady-state temperature distribution will be provided to demonstrate these facts.</u>**

Review Questions

- **NRC Question 3-3**
  - **Provide a description of how the solar absorptivity values listed in Table 3-6 of the SAR were actually applied to the thermal model.**
  - **Application of solar absorptivity values to the package surfaces can serve to decrease the amount of energy absorbed by a package, thereby, reducing the intended values for insolation as outlined in 10 CFR 71.71(c)(l).**
- **AREVA proposed response**
  - **Solar absorptivity value in Table 3-6 was applied by multiplying the incident insolation value at package surface for given time of the day by Table 3-6 value to yield amount of solar energy absorbed by package. Approach is consistent with NUREG-1609, §3.5.2**
    - **Thermal absorptivities and emissivities are to be appropriate for package surface conditions.**
  - **Similar directions are provided in RegGuide 7.9, Rev. 2, §3.2.1. Further details of the solar modeling are provided in Section 3.5.2 of SAR.**

Review Questions

- **NRC Question 3-4**
  - **Provide a clarification of the sequence of events related to the fire test of the MAP certified testing unit (CTU), with particular attention to when the test was concluded and what means were used to extinguish the pool fire.**
  - **It is not clear from the description provided in Section 3.4.2, page 3-22, of the SAR what the actual sequence of events was related to the end of the fire test of the MAP CTU. The regulation in 10 CFR 71.73 clearly prohibits the use of fire suppressants to stop any combustion that may occur on or in a package that is being tested following the conclusion of the fire test. The SAR states that a fire suppressant foam was used to attempt to suppress the fire, but it is not clear if this foam served to provide cooling to the CTU as well.**
- **AREVA Proposed response**
  - **The fire suppressant was introduced to test setup approximately 31 minutes after pool was ignited. Fire suppressant was introduced to test setup via piping below surface of the fuel pool. At no time did fire suppressant make contact with any portion of the package or serve to cool package, nor did suppressant stop any combustion occurring in or on the package. <u>Section 3.4.2 of the SAR will be revised to include this clarification.</u>**

Review Questions

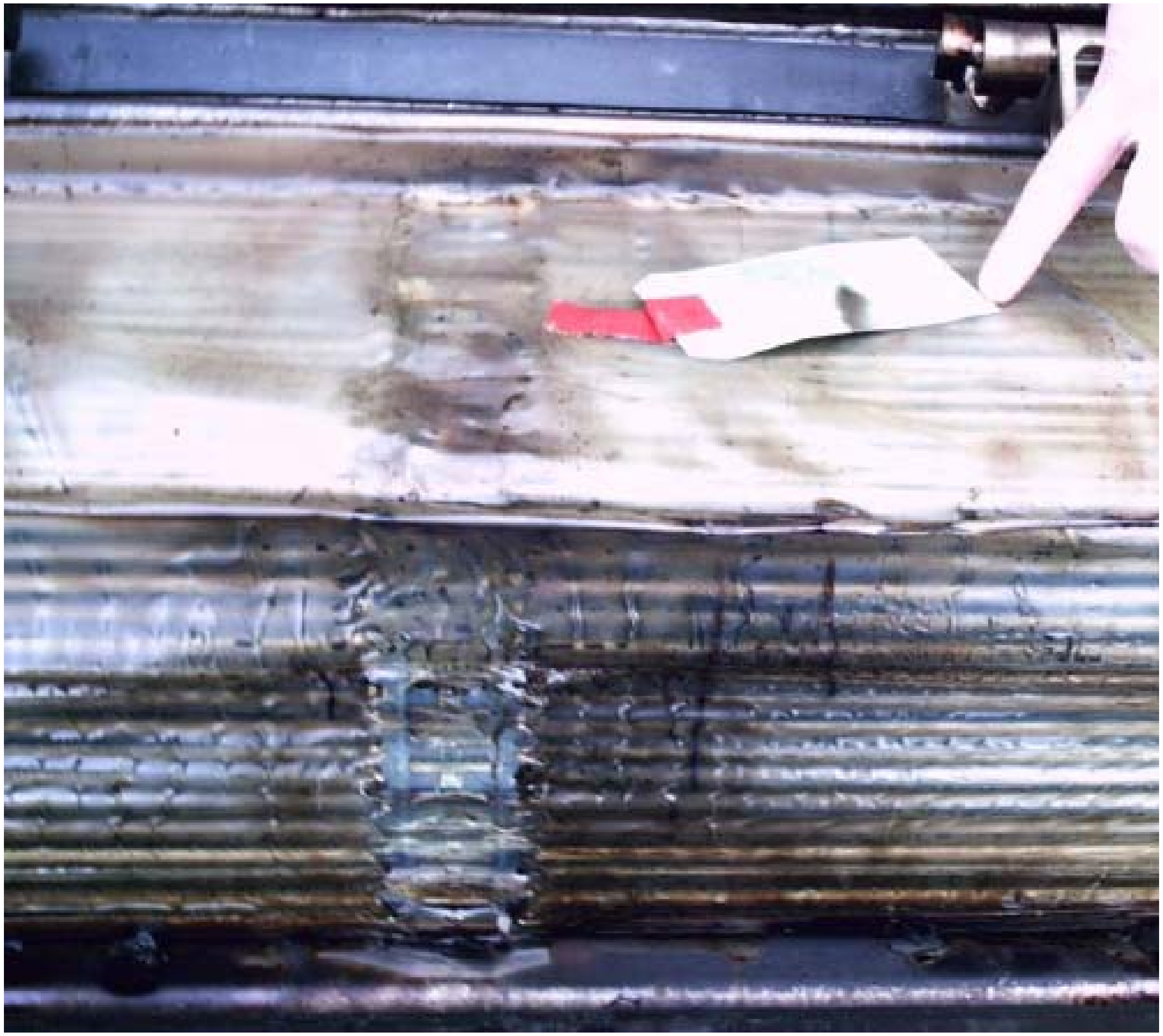
- **NRC Question 3-5**
  - **Justify the claim that the test fire generated twice the heat input to the package than the regulatory 800°C 30 minute fire.**
  - **Section 3.4.2, page 3-23, estimated the fire had twice the heat input of a regulatory fire due to the higher temperature and longer duration, as radiative heat transfer scales as absolute temperature to the fourth power. However, only the heat transfer due to radiation would be two times larger than a regulatory fire, not the total heat flux. Further justification of this statement is needed. If AREVA believes the fire test exceeded the regulatory requirements, then a clear, quantitative discussion of the conservatisms present in the fire test should be presented.**
- **AREVA proposed response**
  - **Intent was to simply state that fire test resulted in package being exposed to a higher heat input than regulatory 800°C 30 minute fire. An accurate determination would involve a complex computation of the transient temperatures of all components, etc.,**
    - **Estimate of twice the heat input was based on heat transfer between an assumed package skin temperature of 1475°F for a regulatory fire and 1746°F for the fire test, a foam char temperature of approximately 650°F, an effective emissivity exchange factor of 0.9, and a convection coef. of 3.5 Btuh/sq. ft-F.**
  - **Heat input per hour for a regulatory fire ((1475+460)^4 – (650+46)^4)*0.9*1.714e-9 + (1475-650)*3.5 = 22172 Btuh/sq-ft. Heat input for the observed fire test ((1746+460)^4 – (650+46)^4)*0.9*1.714e-9 + (1746-650)*3.5 = 38026 Btuh/sq-ft. Ratio of heat input (38026*38 minutes)/(22172*30 minutes) = 2.2**
  - **Heat input ratio is only an estimate and its exact level is not directly important to safety evaluation. <u>SAR text will be revised to simply state that heat input to package as a result of fire test exceeded regulatory requirements.</u>**

Review Questions

- **NRC Question 3-6**
  - **Provide a detailed description of the temperature sensitive strips used during thermal testing and a rationale for their use over other methods of measuring temperatures inside the package during the HAC fire test. Provide additional justification for the accuracy of predicted temperatures for components internal to the package.**
  - **Section 3.4.3.1, page 3-23, of the SAR states that temperatures inside the package were to be measured with temperature sensitive strips, which were unreadable due to condensation from foam out-gassing, causing the temperatures to be estimated from the extent of damage to each package component. Given this, temperature sensitive strips appear to be a less than ideal choice for this application. The temperatures reported in the SAR need to be more accurate in order to make a safety finding.**
- **AREVA proposed response**
  - **Temperature indicating strips were Tempil Thermax THE06S-8. Temperature indicating strips were used because the expected peak temperature inside package was relatively low, use of thermocouples would require altering package to route leads. CTU's dropped prior to fire test, no way of protecting T/C leads extending beyond surface of package without risking integrity of drop test results - protective covers required for leads. Adding T/C's after drop tests was not an option as packages could not be opened/re-closed to post-drop configuration.**
  - **Estimating peak temperatures attained in a fire based on condition of components. The fuel assembly has an accident temperature limit of 1,058°F (570°C) or higher, whereas polyethylene wrap surrounding the fuel assembly has a melting point of 230 to 275 °F. Given that polyethylene wrap was essentially un-damaged and the large thermal margin between 1,058°F and 275 °F, the accuracy of the predicted temperatures is deemed sufficient to assess the safety of package design.**

- **Polyethylene wrap removed – bright finish of assembly with no surface oxidation or tar deposits**

- **Polyethylene wrap and assembly release tag intact**



▶Polyethylene wrap and neoprene – adhesive degraded

NRC Question 3-7

- **Provide a complete description of the physical state of the neutron moderator components after the HAC fire test. Include photographs of those components if available (reference Section 3.4.3.1 of the SAR).**
- **One of the criteria by which the package design is to be evaluated is how the neutron moderator components survive the HAC fire test. Therefore, the staff requires all possible information relating to their condition after the fire.**

AREVA proposed response

- **<u>Additional pictures and data table will be added to the SAR.</u>**

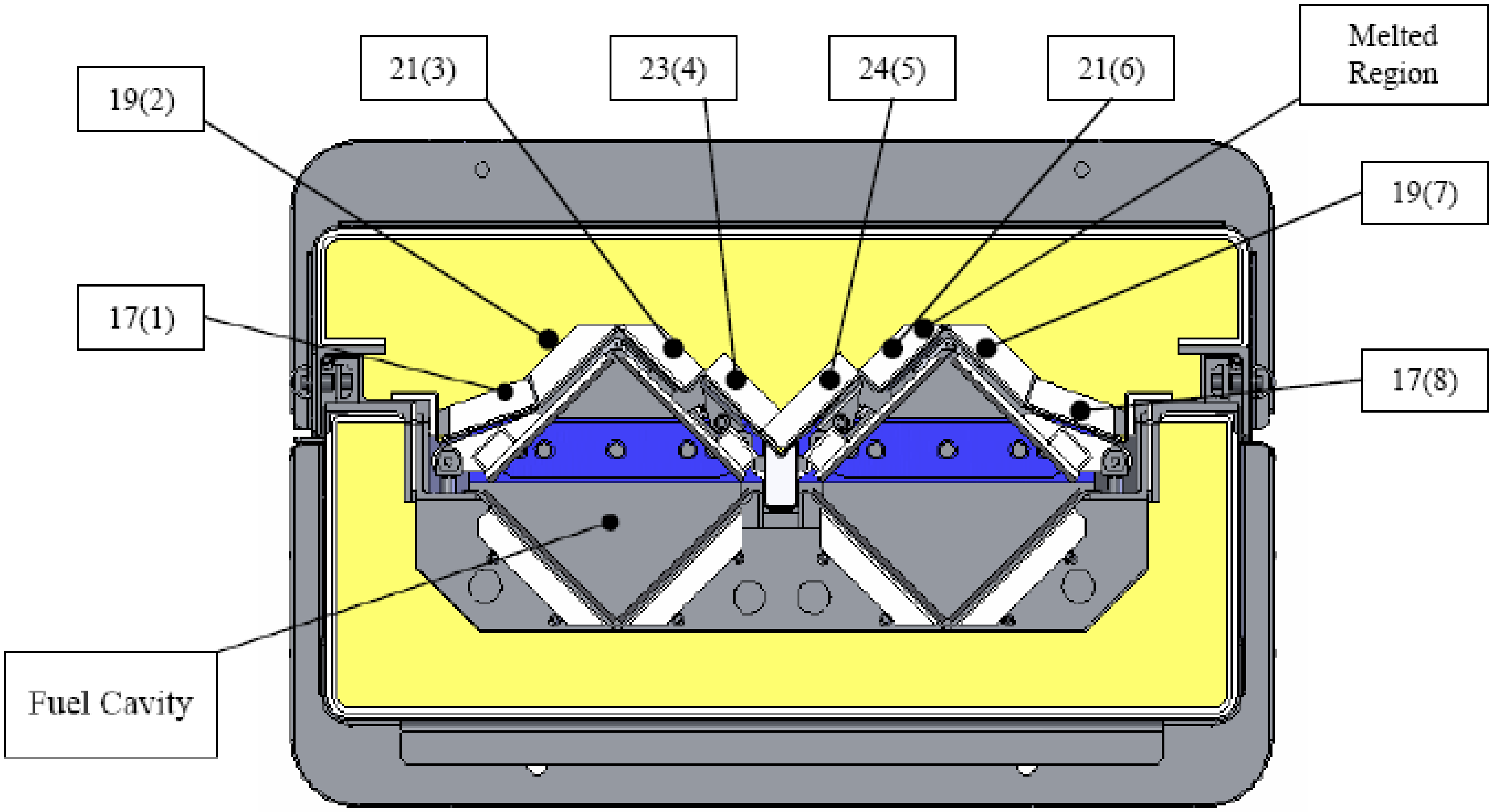
- **Nylon 6,6 emerging worst case melted section in lid**

Review Questions

- **Nylon 6,6 worst case melted section in lid after high pressure water wash – top view**

- **Nylon 6,6 worst case melted section in lid after high pressure water wash – bottom view**

Nylon 6,6 lid package profile



▶ Nylon 6,6 base section with no evidence of melting

Review Questions

NRC Question 3-8

- **Provide a detailed description of the behavior of the intumescent char layer of polyurethane foam described in Section 3.5.3 of the SAR, specifically with regards to its expansion, and the structural stresses it may incur in the package shell.**
- **A property of intumescent polyurethane foam is expansion to seal any holes in the outer shell caused by puncture damage during the fire exposure. However, according to design drawings, it appears that in certain areas of the package, the foam has no room to expand. Depending on the amount of expansion the foam undergoes as it decomposes, it could cause additional structural stresses.**

AREVA proposed response

- **The char has no appreciable structural capacity and will not develop unless there is already space available. Without available space pyrolysis gases developed as a result of charring process will move char mass out through vent ports and prevent its buildup. Only as the charring process continues and space becomes available will char be retained, filling available space.**
- **The foam char has no appreciable structural capacity and can not produce stress in the package shell.**
- **<u>The SAR text will be revised to clarify these points.</u>**

AREVA

Review Questions

- **NRC Question 3-9**
  - **Provide a comparison of the NCT analysis conducted in SlNDA/FLUlNT and the observations of NCT (pre-fire) temperatures of the actual MAP CTU (reference Section 3.5.2.1 of the SAR).**
  - **Typically, when analytical (computer based) models are presented for a package design, there is some comparison made between the analysis model results and any experimental results, if physical testing was conducted, in order to validate the predications of the analytical model. The applicant has provided an analysis to predict NCT temperatures as well as test results for HAC. There is no nexus drawn between the analytical modeling and the experimental test results. Comparisons of this type serve to strengthen the demonstration of thermal performance of the package when they are presented.**
- **AREVA proposed response**
  - **As stated in Section 3.4 of SAR, test results for HAC condition is via physical testing and <u>not</u> by analytical modeling. Only use of analytical model for HAC event was as test planning tool to predict how long it would take to cool or heat package to drop test conditions. Verification of test article's condition prior to drop test based on physical measurements via temperature probes inserted into package vent ports and not by analytical predictions. No part of safety basis for package under HAC conditions used analytical model.**
  - **None of physical testing was conducted to validate the predictions of analytical model. Further, thermal conditioning prior to the physical testing was not conducted in a manner that would permit its use in validating analytical model.**
  - **Package has essentially no decay heat, need to validate analytical model is not important to safety analysis since peak temperatures of components under NCT conditions can not exceed local ambient-solar temperature.**

Review Questions

NRC Question 3-10

- Provide a summary in Section 3.5.3 of the SAR of the physical properties of charred/decomposed polyurethane foam (e.g., specific heat, thermal conductivity, density, etc.). If these properties are not available, provide a justification for the exclusion of these properties from the SAR. Include a discussion of the intumescence of the foam and what effects the foam material reaction could have on the other materials of the package.
- Information about the decomposed foam is necessary for confirmatory analyses of the performance of the package in response to HAC conditions. References for this information should be cited in the SAR.

AREVA proposed response

- Physical properties of charred/decomposed polyurethane foam are not available. The non-availability is due to a charred foam structure that is too fragile to permit consistent testing of samples and fact that exact makeup of char is not repeatable between test setups.
- Confirmation of package design is by test and not analysis (as allowed by 10 CFR 71.73 (c)(4) and NUREG-1609, 3.5.3), properties of charred foam are not needed nor required for safety determination. Demonstration of safety of package design is evidenced by the condition of safety components of package (i.e., nylon moderator and fuel assemblies) after fire.
- Foam material reactions during charring have not been observed having an effect on other materials in package for this application nor for any of numerous other packages for which has it been used.

Review Questions

- **NRC Question 3-11**
  - **Provide the rationale for conducting the "bucket tests" (mentioned in Section 3.5.3) as a means to determine the correlation between foam recession depth and density. Discuss how the bucket tests influenced the testing and evaluation of the MAP 12fMAP-13 packages, and provide justification of the applicability of the bucket tests to the foam as it was used in the package.**
  - **The value of the bucket tests that were conducted on the foam is not clearly described in the SAR. Additionally, this relationship of foam density to recession rate only applies when the fire conditions (heat, duration, etc.) and material configuration (surface area, depth, etc., of each material) are reasonably close to the bucket test, which may not be the case for the fire test. It appears that measuring the amount of decomposition (which could be easily correlated to the recession depth) as a function of heat input, or temperature, could provide more useful information. This could be used to estimate the heat input or highest temperatures seen during the fire test by examining the recession depth of the charred foam.**
- **AREVA proposed response**
  - **“Bucket tests” described in Section 3.5.3 were not conducted to determine correlation between foam recession depth and density. Correlation of foam recession was provided by foam vendor (see footnotes 9 & 10). Bucket tests were conducted as a design verification process prior to proceeding to full scale test unit fabrication. Reason for mentioning bucket tests was simply to indicate that results seen from full scale fire test were viewed as consistent to bucket tests. This consistency of results demonstrates observed performance of package design under full scale testing was not abnormal, but would be repeatable for a similar setup. This discussion is consistent with last sentence in NUREG-1609, §3.5.3.3.**
  - **<u>SAR text will be revised to clarify these points.</u>**

NRC Question 4-1

- **Correct the inconsistency for the cladding leakage rate mentioned in Section 4.2.3, page 4-3, and in Section 8.1.4, page 8-2. Also specify the type of gas used for the leak test.**
- **Section 4.2.3, says that "the containment boundary is less than 3E-08 ref-cc/sec."Section 8.1.4 says, "the leak rate is typically less than 1 E-7 atm-crn3/sec." The post fabrication leakage test for the fuel rods should be clearly and unambiguously stated in both sections.**

AREVA proposed response

- **The SAR text in Section 4 will be revised to be consistent with Section 8.**

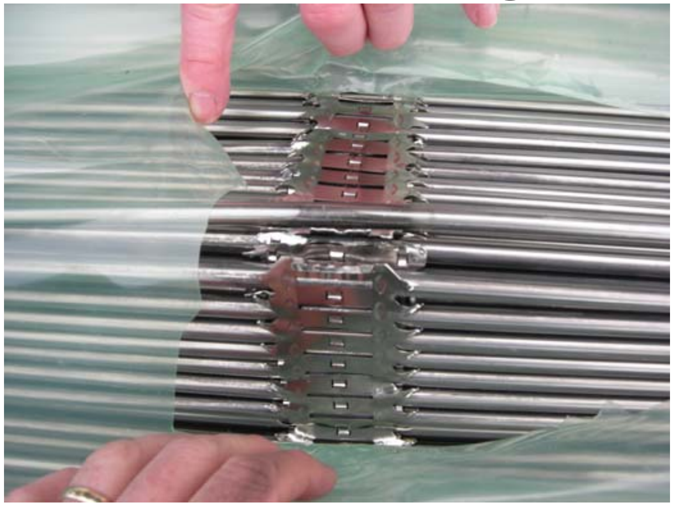
Review Questions

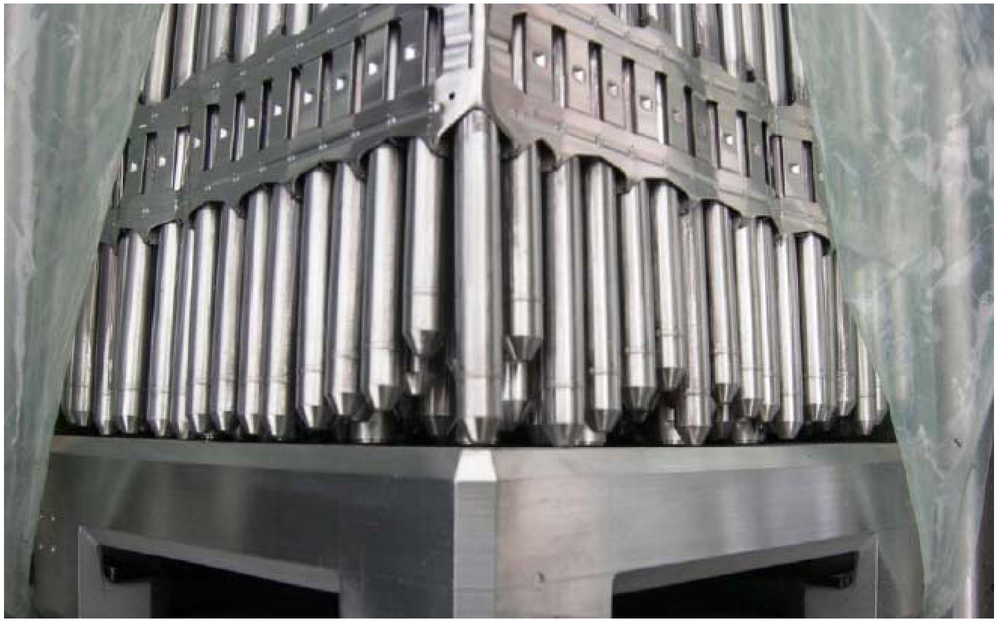
- **NRC Question 4-2**
  - **Provide justification in the SAR that the cladding can withstand HAC in the form of drop test and fire test results, such that the containment boundary remains unbreached. Also, describe the condition of the cladding after being subjected to HAC.**
  - **Section 4.3.2.2 states: "The performance tests documented in Section 2 [of the SARI demonstrates that no pellets are released from the cladding as a result of the postulated hypothetical accident conditions." Contrary to this statement no material could be identified in the SAR that describes the condition of the cladding after being subjected to HAC.**
- **AREVA proposed response**
  - **Section 2 will be revised to include a description of the cladding following the drop and fire tests:**
  - **A visual inspection of the fuel rods in the CTU did not identify any bent or damaged rods. Test assemblies were removed from CTU and further inspected, and no cracked or breached rods were identified visually. Random sample of rods was removed from most damaged assembly and checked for pressurization. All were pressurized. No leakage or breach of rods occurred as a result of performance tests. Interior of package coated with tars as a result of condensation of foam off-gas; fuel rods, being covered by a thin sheet of polyethylene, remained in their as fabricated bright condition. The HAC fire test had no further effect on cladding.**

- **Polyethylene wrap removed after drop and fire test CTU3– no bent or damaged rods**

Review Questions

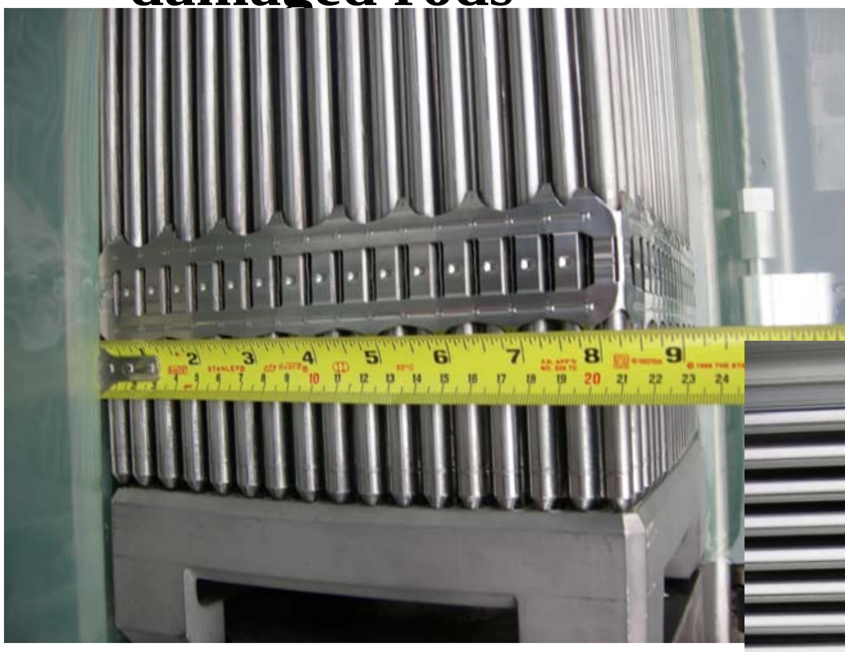
- **Polyethylene wrap removed CTU1– no bent or damaged rods, midspan grid damaged, rod removed but not damaged**

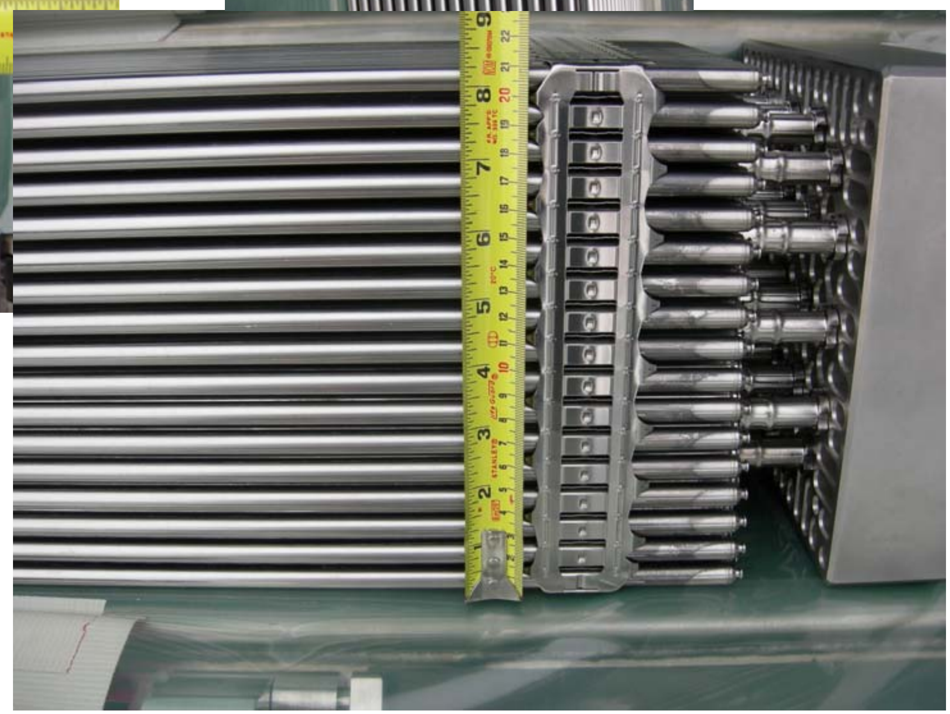




Review Questions

- **Polyethylene wrap removed CTU2– no bent or damaged rods**





Review Questions

- **NRC Question 4-3**
  - **a) State in the SAR whether or not the dummy fuel assembly in the CTUs had the fuel tubes pressurized. Also, if the CTUS rods were not pressurized, explain what effect pressurized rods would have on cladding integrity resulting from HAC.**
  - **b) Explain how the CTUs with a dummy fuel assembly bound the case of shipment of loose rods in a container for the HAC tests. Also, evaluate any additional effect on the loose rod cladding integrity resulting from the HAC tests.**
  - **The staff needs this information to ascertain whether or not the dummy fuel assembly adequately represents the fuel being shipped in the drop tests. For example, the drop tests only include a dummy assembly which would tend to reduce bending forces on an individual rod by reinforcing it with the combined strength of the assembly.**
- **AREVA proposed response**
  - **<u>Section 2 will be revised to include the rod pressure information:</u>**
  - **The CTU rods were pressurized to the maximum design pressure for current assembly designs, 225 +0/-15 psig.**
  - **Loose rods will not be shipped in the MAP.**

Review Questions

- **NRC Question 4-4**
  - **Include in the SAR the weight of fuel that is equivalent to an A, quantity and the likelihood of it escaping from the post-HAC of the cladding.**
  - **This information is needed to clarify exactly how much fuel could be released after a postulated accident and still be below an A, value.**
- **AREVA proposed response**
  - **Assemblies containing low-enriched commercial grade uranium dioxide, A2 value is unlimited; no corresponding limiting weight. Assemblies containing blended low-enriched (BLEU) uranium dioxide, from Section 4 mixture A2 value is 0.175 Ci and specific activity of material is 0.0143 Ci/kg. The limiting mass for Type A shipment of BLEU material is 0.175/0.0143=12.2 kg (about 1,500 pellets).**
  - **Packaging used for low-enriched commercial grade uranium dioxide is same packaging used for BLEU material. Additionally, leak tests used to confirm integrity of BLEU fuel rods to a rate less than 1E-7 ref-cc/sec is same as used for low-enriched commercial grade rods. Leakage rate of low enriched commercial grade material following 10CFR71.73 HAC sequence of tests is expected to be same as that demonstrated for the BLEU material in Section 4. Leakage requirement for low enriched uranium dioxide is no dispersal, limit established for package based on BLEU material bounds limit for low-enriched commercial grade material.**
  - **<u>This information will be added to Section 4.</u>**

Review Questions

- **NRC Question 4-5**
  - **State the initial pressure in the fuel rods in the SAR. It is suggested to include this as an addition to Table 1-1 or 1-3.**
  - **This information is needed to provide an accurate description of the fuel being shipped and it provides a mechanism for propelling particulates from a failed fuel rod, or in this application, the containment boundary.**
- **AREVA proposed response**
  - **CTU rods were pressurized to maximum design pressure for current assembly designs, 225 +0/-15 psig. <u>Information will be added to performance test discussion in Section 2 per RAI question 4-3. Typical pressure will be listed in Table 1-3.</u>**
  - **Pressure of rods used in the CTU is highest rod pressure currently manufactured by AREVA. Following 10CFR71 HAC performance tests, no leakage was observed. Post-test leakage rate is same as pre-test leakage rate (on the order of 1E-7 ref-cc/sec) and the expected leakage rate is much less than allowable post-HAC leakage rate (2.25E+3 ref-cc/sec assuming aerosol leakage). Significant margin to allowable leakage rate.**
    - **Aerosol leakage assumption conservative, essentially no damaged fuel rods resulting from HAC tests and past experience with handling pellets indicates sintered pellets do not release particulates (if at all).**
  - **Mass density used to calculate allowable leakage rate for the BLEU material (9E-6 g/cc) is reasonable bounding assessment per ANSI N14.5-1997 for powder materials. Sintered pellets will be used in the assemblies, use of this value is extremely conservative and adds additional margin to evaluation.**
  - **Margin to allowable is significant (more than 1,000 times less than allowable) and differential leakage due to initial differential rod pressure is considered negligible.**

Review Questions

- **NRC Question 6-1**
  - **Justify the statement: "any form of borated aluminum that satisfies the 10B areal density requirement is acceptable," in Section 6.2.1.3.2.1, page 6-8, of the SAR.**
  - **It has been NRC practice for approved containers to permit only absorber materials that have been properly qualified, have sufficient durability for the application, and require acceptance standards on fabricated neutron absorber plates to be used in casks licensed under 10 CFR Part 71. Qualification and acceptance tests of the material are comparatively few when only 75% credit for 10B is to be taken but "any material that contains a boron absorber" would not be suitable.**
- **AREVA proposed response**
  - **The criticality model represented a borated plate at minimum B-10 areal density with a further 75% reduction of B-10 content. Other non-boron constituent materials were not included in criticality model. Borated plates satisfying the minimum B-10 areal density would, in principle, be considered adequate. Section 8.1.5.2 "Neutron Absorber Plates" commits to the use of BORAL absorber with minimum B-10 areal density, which is bounded by criticality model.**

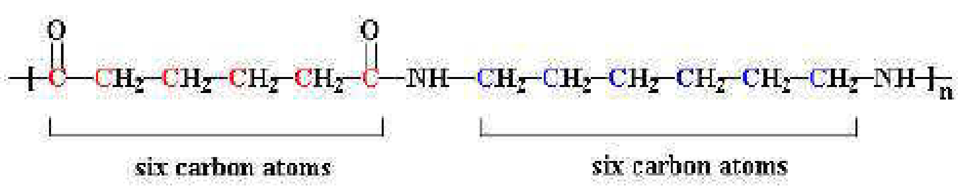
NRC Question 6-2

- **Justify the nomenclature "borated aluminum" as used to represent the commercial product BORAL®.**
- **Traditionally, the term "borated aluminum" has been used to represent a solid solution containing boron. It has not been used to represent a composite of powders that are formed into an absorber material. The description given for BORAL® is the type expected for a composite material.**

AREVA proposed response

- **Borated-aluminum, Boron-aluminum, and also Aluminum-boron have been used to represent multitude of commercially marketed neutron absorbing materials of both ceramic and metal compounds of boron and aluminum. Materials are further characterized by trade names including BORAL®, Boral, and MMC. BORAL® is boron/aluminum material however it is more formally characterized as indicated in Section 8.1.5.2 as a composite Ceramic-Metal aluminum sheet consisting of a core of uniformly distributed boron carbide and aluminum particles which are encased within aluminum.**

- **NRC Question 6-3**
  - **Justify the use of 90% credit given to the moderator block, and 100% theoretical density for the moderator nylon materials.**
  - **Section 6.4.5.1.3, states, "The moderator blocks for the flux trap system are modeled with a uniform dimensional reduction that results in 90% of the total moderator block volume for the flux trap being modeled." The staff is not familiar with the nylon in question. For example, helpful information would be the data source and how manufacturing tolerances and other variables would be expected to influence pertinent properties of moderator materials.**
- **AREVA proposed response**
  - **Nylon used in MAP series of packagings consists of Nylon 6,6. Nylon 6,6 is a polymer consisting of a series of bonded chains with a simplified compound structure of $C_6H_{11}NO$. Widely used in commercial structural applications including automotive, furniture, power tool housings, and lawn and garden equipment. Polymer means “many parts” and refers to molecule formed from many smaller molecules, called monomers, which are linked together into large molecules. Nylon 6,6 is so named because it is synthesized from two different organic compounds, each containing six carbon atoms.**



Review Questions

- **AREVA proposed response to question 6-3 (cont')**
  - **Nylon 6,6 has a manufactured density ranging from 1.13 to 1.15 g/cc. Minimum thickness (1.25") used in MAP package is not influenced by manufacturing tolerances. Manufactured thicknesses range from 1.26" to 1.28". Material is a thermal-plastic with a very high melting temperature ranging from 482 to 509 F. The flash ignition temperature for material is about 752 F.**
  - **Nylon 6,6 is suitable for packaging applications due to it hardness, abrasion resistance, self-extinguishing ability, and high melting and flash ignition temperatures.**
  - **Additional information on Nylon can be found in the Nylon Plastics Handbook, Melvin I Kohan, 1995, Hanser Gardner Publications. Manufacturing data sheets are also available that describe commercially available Nylon. Additional information can also be found via internet search.**
  - **Criticality assessment considered both dimensional and density reductions with dimensional reductions leading to higher keff results. Most reactive modeled condition involved a Nylon 6,6 density of 1.14 g/cc with thicknesses reduced by 10%. Nylon 6,6 at a density of 1.14 g/cc has a Hydrogen density of 11.1%. Reducing the Nylon 6,6 density to 1.13 g/cc reduces the Hydrogen density to 11.0%. Variations in the Nylon 6,6 density within manufactured range have negligible effect on Hydrogen density of compound.**
  - **Variation in density will have a negligible effect on the modeled 90% credit for Nylon 6,6 thickness. Modeled as a reduced thickness, reduction was used to bound minor melting experienced during the HAC fire test and not to bound dimensional manufacturing tolerances. Based on results of fire test, modeled 90% credit for Nylon 6,6 moderator blocks bounds loss experienced in single section. Modeled configuration is therefore very conservative with respect to HAC test results.**

Review Questions

- **NRC Question 6-4**
  - **a) Explain the basis of the criticality safety evaluation under the assumptions that 1) it was based on moderator exclusion; and 2) that the fuel cladding gap was not floodable.**
  - **b) Justify the ability of the fuel cladding to retain its integrity after the HAC tests so as to achieve moderator exclusion.**
  - **Section 6.2.1 .I, page 6-5, of the SAR states that the containment system of the MAP packages consists of the fuel rod cladding. Section 6.4.2.1.1, page 6-16, of the SAR states: "The fuel-clad gap is modeled as void to represent a dry gap. The fuel-clad gap within the fuel rods in the fuel assembly is not considered as floodable based upon the HAC testing results, discussed in Section 6.4.5.4.'' This is not consistent with the requirements set forth in 10 CFR 71.55, which requires the package to be sub-critical even if water were to leak into the containment system.**
- **AREVA proposed response**
  - **Drop and fire tests performed for MAP demonstrate that containment boundary (fuel rod cladding) remains intact and leak-free during all normal and hypothetical accident conditions. Immersion tests further specified in 10 CFR 71 (c)(5) for fissile and (6) all packages, require immersion equivalent to an external water pressure of 21.7 lbf/in^2, however intact and leak-free rods can tolerate much higher pressures and remain moderator free. Moderators are not expected to flood fuel-cladding gap.**
  - **10CFR 71.55 (c) allows exemptions provided that no single packaging error would permit leakage and appropriate measures are taken before each shipment to ensure that the containment system does not leak. Assemblies are handled and packed with great care with no event postulated as being more severe than the HAC. Leak tests are further performed prior to shipment to ensure the containment boundary does not leak.**
  - **However, in order to add additional conservatism to criticality safety assessment, <u>calculations will be revised to include water flooding in fuel-cladding gap.</u>**

- **NRC Question 6-5**
  - **Explain how the fuel-cladding gap can remain dry after the puncture and immersion test.**
  - **Section 6.4.5.4, page 6-29, of the SAR states that fuel rod cladding did not crack and rupture after testing under the HAC described in Section 2.12. The staff reviewed the HAC testing in Section 2.12 and found that the puncture was conducted on the packaging instead of the containment boundary, which is the cladding.**
- **AREVA proposed response**
  - **The package, like most others, utilizes an external shell to protect the containment boundary from external impacts. As required by regulation, the package was tested in its usual assembled condition. Containment boundary is not directly challenged by puncture ram or penetration rod drop. This is typical for any radioactive materials shipping package.**
  - **The external shell is required to ship the materials; the shipping package performance tests are representative of actual shipping conditions and demonstrate that cladding breach does not occur.**
  - **In order to add additional conservatism to criticality safety assessment, calculations will be revised to include water flooding in fuel-cladding gap.**
    - **May need to reduce pellet density to 98% or include guide tube material.**

AREVA

Review Questions

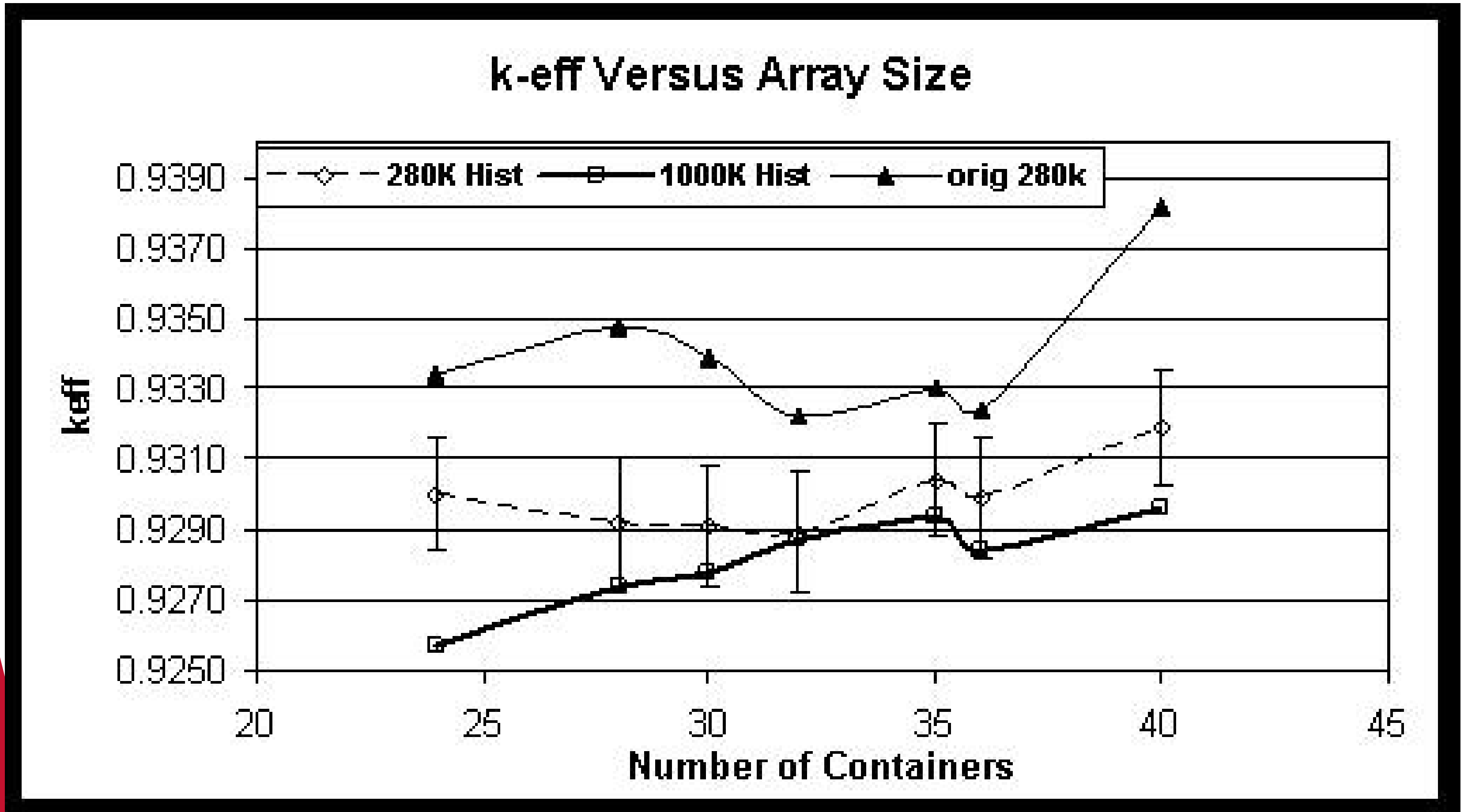
NRC Question 6-6

- Provide an explanation on the behavior of the keff curves as a function of the package array size, in Figure 6-29.
- Figure 6-29 shows the change of keff as a function of package array size with the FLIP1 configuration. From this figure, it can be observed that the keff value increases first, and then goes down as the number of packages increases. Finally, the keff value jumps from 0.9356 to almost 0.9420. This curve does not seem to be consistent with common understanding of the physics of a fissile system.

AREVA proposed response

- Package array variation, statistics and small span on the keff axes exaggerates trend. Rerunning cases supporting the figure with 280K (UNIX) and 1000K (PC) histories shows more uniform trend (280K). Case with 1000K histories indicates an easily explained trend and illustrates that while smaller number of histories provided conservative values, trend is not quite right. However, both sets are generally within statistical uncertainty. Correct trend observed and the comment easily resolved as due to statistical uncertainty for PC with 1000K histories.

- AREVA proposed response to question 6-6 (cont')



Review Questions

- **NRC Question 1-1**
  - **Clarify the discrepancy between the cover letter and Section 1.2.2.2, page 1-10, of the SAR regarding the justification for a "Type B" classification of the MAP-12/MAP- 13 packages.**
  - **The cover letter of the application states: "Since this material constitutes Type B material due to the U-236 content, the shipment and use of this fuel is directly dependant upon the implementation of the MAP shipping package ...[.] "Section 1.2.2.2 of the SAR states: "The increase in 234U causes the contents to fall under the Type B requirements." It is not clear as to the reason AREVA is requesting a "Type B" classification for the Model No. MAP-12/MAP-13.**
- **AREVA proposed response**
  - **<u>The text in Section 1.2.2.2 will be revised to be consistent with the cover letter.</u> U-234 is attributed to the bulk of the radioactivity of material however the increase in U-236 causes contents to fall under Type B requirements.**

- **NRC Question 1-2**
  - **Confirm that AREVA is not seeking approval for the transportation of loose fuel rods per the current version of the application. Section 1 .I, Page 1-1, of the SAR states: "The MAP package is designed to transport both Type A and Type B fissile material in the form of unirradiated nuclear fuel assemblies or loose rods containing sintered uranium dioxide fuel pellets enriched up to 5.0 weight percent 235U." Chapter 6 of the SAR, however, does not provide a criticality evaluation for the loose fuel rod contents in the MAP-12/MAP-I3 packages. This information is needed to determine compliance with 10 CFR 71.35. 1-3 Explain how the CSI value of 2.8 was obtained. Also explain the application of the CSI value to the loose fuel rod contents in the MAP package.**
  - **Section 1.1, page 1-1, of the application states the MAP'S CSI is 2.8 for fuel assemblies and loose fuel rods; however there is no criticality evaluation provided in the SAR for the loose fuel rods in the MAP package.**
- **AREVA proposed response**
  - **AREVA is not seeking approval for the transportation of loose fuel rods.**

Review Questions

- **NRC Question 1-3**
  - **Explain how the CSI value of 2.8 was obtained. Also explain the application of the CSI value to the loose fuel rod contents in the MAP package.**
  - **Section 1 .I, page 1-1, of the application states the MAP'S CSI is 2.8 for fuel assemblies and loose fuel rods; however there is no criticality evaluation provided in the SAR for the loose fuel rods in the MAP package.**
- **AREVA proposed response**
  - **The CSI value of 2.8 was based on the criticality assessment performed in Section 6 for a 36 package configuration.**
  - **2N=36, N=18**
  - **50/18 = 2.77778, which is rounded to 2.8.**

Review Questions

NRC Question 2-1

- **Provide the discussion and/or analysis to demonstrate the structural integrity of the cladding during hypothetical accident conditions (HAC).**
- **The fuel rod cladding is considered to provide containment of radioactive material under both normal conditions of transport (NCT) and HAC. Section 2.11 states that the discussion of cladding and its ability to maintain sufficient mechanical integrity to provide such containment is described in Section 1.2.2 and Chapter 4.0 of the SAR. No such discussions were found to verify the structural integrity of the cladding during HAC.**

AREVA proposed response

- **<u>Section 2 will be revised to include a description of the cladding following the drop and fire tests:</u>**
- **Visual inspection of fuel rods in CTU did not identify any bent or damaged rods. Test assemblies were removed from CTU and further inspected, no cracked or breached rods identified visually. Random sample of rods removed from most damaged assembly and checked for pressurization. All found to be pressurized. No leakage or breach of the rods occurred as a result of performance tests. Interior of package was coated with tars as a result of condensation of foam off-gas; however fuel rods, being covered by a thin sheet of polyethylene, remained in as fabricated bright condition. HAC fire test had no further effect on cladding.**