72-1025
72-1015

NAC INTERNATIONAL

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August 9, 2002

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
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Attention: Document Control Desk

Subject: Submittal of Notification of Spent Fuel Dry Storage Shielding Code Limitations

NAC-UMS®, Docket No. 72-1015, and NAC-MPC, Docket No. 72-1025

References:
1. Final Safety Analysis Report (FSAR) for the NAC Multi-Purpose Canister (NAC-MPC) System, Amendment 1, NAC International, February 2002
2. Certificate of Compliance (CoC) No. 1025, Amendment 1, for the NAC International Multi-Purpose Canister (MPC) System, United States Nuclear Regulatory Commission, November 13, 2001
3. Certificate of Compliance (CoC) No. 1015, Amendment 2, for the NAC International UMS® Universal Storage System, U.S. Nuclear Regulatory Commission, December 31, 2001
4. Final Safety Analysis Report (FSAR) for the UMS® Universal Storage System, Amendment 2, NAC International, January 2002
5. Conference call between the NRC and NAC, August 5, 2002

In accordance with the Reference 5 conference call, NAC International (NAC) herewith provides the attached notification of a limitation discovery on the use of the spent fuel dry storage cask shielding code, SCALE/MORSE, in calculating dose rates at the air inlets of some vertical concrete casks (VCC).

NAC is the Certificate of Compliance (CoC) holder for the NAC-UMS® spent fuel dry storage cask, certificate no. 72-1015 (Reference 3), and the NAC-MPC dry storage cask, certificate no. 72-1025 (Reference 2). NAC has discovered a limitation in the SCALE/MORSE shielding analysis code to conservatively predict the radiation dose rates at the air inlets on the NAC-UMS® and NAC-MPC dry cask storage system designs. This limitation does not affect the ability of structures, systems, and components (SSCs) important to safety to perform their intended safety function and, therefore, is not reportable under the requirements of 10 CFR 72.242(d). In addition, this limitation could not create a substantial safety hazard and, therefore, is not reportable under 10 CFR Part 21. Compliance with the 10 CFR 72.236(d) dry storage cask shielding requirements is also not affected by this analysis code limitation.

As described in the attachment, NAC identified the MORSE code limitation during a review of the calculated dose rates presented in the NAC-MPC FSAR versus the measured dose rates for the first NAC-MPC System loaded and placed in service at the Yankee Rowe site. The FSAR calculated dose rates are conservative, as expected, except at the locations of the air inlets in the VCC. Based on the similar geometry of the NAC-UMS® VCC air inlets, NAC is revaluating the dose rate calculations for the NAC-UMS® System being implemented at Maine Yankee.

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Although no deficiency in any structure, system or component (SSC) exists, the attached notification is being provided to the NRC as a voluntary action by NAC to inform the NRC of the limitation of the SCALE/MORSE code and is formatted to provide information consistent with 10 CFR 72.242(d). NAC has notified the users of the NAC-UMS® and NAC-MPC dry cask storage systems of this limitation, and those users have been involved in determining the appropriate remedial actions. In addition, NAC notified Bryan Broadhead at Oak Ridge National Laboratory of this SCALE/MORSE code limitation by telephone on July 25, 2002.

If you have any questions regarding this submittal, please contact me on my direct line at 678-328-1321.

Sincerely,

T C Thompson

Thomas C. Thompson
Director, Licensing
Engineering & Design Services

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Keith Waldrop (Duke)

Attachment

Spent Fuel Dry Storage Cask Shielding Code Limitations

(1) Brief abstract describing the limitation, including all component or system failures that contributed to the limitation and corrective action taken or planned to prevent recurrence, and why the deficiency does not affect the ability of structures, systems, and components (SSCs) important to safety to perform their intended safety function.

NAC International (NAC) is the Certificate of Compliance (CoC) holder for the NAC-MPC dry storage cask, certificate no. 72-1025, and the NAC-UMS® spent fuel dry storage cask, certificate no. 72-1015. During the initial design and certification, NAC performed shielding evaluations for the NAC-MPC and NAC-UMS® Cask Systems using the SCALE 4.3 SAS4 sequence (MORSE) code to calculate cask surface dose rates. After loading spent fuel in the first cask of the NAC-MPC design at the Yankee Rowe site, the four air inlet surface dose rates were measured and found to be about 50% higher than predicted by the SCALE/MORSE code calculations. The measured dose rates at 20 other points on the loaded cask were all within the values calculated using the SCALE/MORSE code. After reviewing the NAC-MPC shielding analyses, NAC has concluded that the SCALE/MORSE code has a limitation associated with calculating dose rates at the air inlets of certain dry storage cask designs.

There have been no NAC-UMS® casks loaded with spent fuel, as of this date, so there is no empirical data for the NAC-UMS® design to compare with the SCALE/MORSE calculated surface dose rates. However, the NAC-UMS® air inlet design is very similar to the NAC-MPC design and, therefore, the SCALE/MORSE code air inlet dose rate calculation limitation is expected to also apply to the NAC-UMS® design.

NAC is recalculating the air inlet and outlet dose rates for the NAC-MPC and NAC-UMS® designs using the ANSWERS software package containing the MCBEND code. NAC is also re-running the MORSE evaluations in analog mode, without code biasing. The NAC-MPC and NAC-UMS® Final Safety Analysis Reports (FSARs) will be updated to reflect revised calculated air inlet dose rates that are conservative with respect to the measured values, and to identify the code(s) used to calculate the revised values.

The non-conservative calculation of the air inlet dose rates for the NAC-MPC and NAC-UMS® designs does not affect the ability of the cask structures, systems, and components (SSCs) important to safety to perform their intended safety function. The calculated air inlet dose rates are compiled with the other calculated cask surface dose rates as input to an evaluation that demonstrates generically that the cask design will be able to meet 10 CFR 72.104 offsite dose limits at ISFSI sites. The air inlet surface represents less than 1% of the total cask surface area. Although the air inlet dose rates were underpredicted by the initial design shielding analyses, the remainder of the cask surface dose rates were conservatively predicted, and the compilation of all surface dose rates, including the air inlet dose rates, continued to be conservative and did not change the results of the 10 CFR 72.104 evaluations reported in the NAC-MPC and NAC-UMS® FSARs. Further, each ISFSI general licensee is required by 10 CFR 72.212 to perform a site-specific evaluation to assure compliance with the 10 CFR 72.104 limits for their ISFSI configuration and cask dose rates. Finally, each ISFSI licensee will monitor the actual site boundary dose rates to verify compliance with 10 CFR 72.104 limits.

The non-conservative air inlet dose rate calculations also had no effect on compliance with the 10 CFR 72.106 accident dose limits, or on compliance with the 10 CFR 72.236(d) requirement to provide radiation shielding to meet the 10 CFR 72.104 and 72.106 requirements. The non-conservative air inlet dose rate calculations do not affect compliance with the occupational exposure limits in 10 CFR 20 because the ISFSI general licensee ensures compliance with the 10 CFR 20 limits by utilizing actual measured dose rates, and not the FSAR calculated design dose rates.

The Appendix A Technical Specifications (TS) for both the NAC-MPC and NAC-UMS® CoCs contain a Limiting Condition for Operation (LCO) that identifies cask surface dose rate limits (LCO 3.2.1 for NAC-MPC CoC Amendment 1 and LCO 3.2.2 for NAC-UMS® CoC Amendment 2). However, a loaded cask can be stored with surface dose rates higher than the LCO limits by compliance with Actions A.1 and A.2 of the LCO to administratively verify the correct fuel loading and perform analysis to verify compliance with the radiation protection requirements of 10 CFR 20 and 10 CFR 72. Although storage of design basis fuel in a cask could have resulted in measured average air inlet and outlet dose rates outside the Technical Specification values because of the non-conservative air inlet dose rate calculations, an ISFSI licensee would be able to comply with Actions A.1 and A.2 to remain in compliance with the Technical Specifications.

(2) A clear, specific, narrative description of what occurred so that knowledgeable readers familiar with the design of the spent fuel storage cask, but not familiar with the details of a particular cask, can understand the analysis code limitation.

During the initial cask design and certification, NAC performed shielding evaluations for the NAC-MPC and NAC-UMS® spent fuel dry cask storage systems using the SCALE 4.3 SAS4 sequence (MORSE) code to calculate cask surface dose rates. The calculated dose rates were reported in Section 5.4 of the Final Safety Analysis Reports (FSARs) for NAC-MPC (CoC No. 72-1025) and NAC-UMS® (CoC No. 72-1015). Maximum air inlet dose rates were calculated to be 99 mrem/hr for the NAC-MPC design, and 7 mrem/hr for the NAC-UMS® design, with the UMS® design containing a significant augmentation of the air inlet structure for shielding.

After loading the first NAC-MPC System at Yankee Rowe with fuel containing approximately 66% of the design basis heat load, measured dose rates were significantly lower (conservative) than calculated, as expected, with the exception of the air inlet dose rates. The measured air inlet dose rates were about 50% higher than the calculated values for the loaded spent fuel (about 66% of design basis heat load), but the average of the air inlet and outlet dose rates was within the values of NAC-MPC CoC Appendix A Technical Specification A 3.2.1.

A review of the NAC-MPC system shielding calculations indicated a combination of two code limitations associated with modeling air inlet dose rates that were not apparent prior to the cask loading. For the NAC-MPC design, three-dimensional (3-D) MORSE results for a vertical concrete cask (VCC) containing a 1-inch base plate were scaled by one-dimensional (1-D) evaluation results for a VCC with a 2-inch base plate to obtain the NAC-MPC FSAR maximum reported air inlet dose rates. Measured results indicate that the potential for radiation streaming, i.e., by-passing the increased thickness base plate, result in the possibility of under-estimating the dose rate for the as-built VCC with a 2-inch base plate. During confirmatory 3-D SCALE/MORSE evaluations of a VCC with a 2-inch base plate, a limitation in the applicability of the SAS4 MORSE Monte Carlo biasing structure became apparent. The radial 1-D biasing structure employed in SAS4 shielding evaluations produces very low probability, high weight, particles impacting the inlet detector. This results in a detector response that does not follow a normal distribution and produces uncertainties that do not converge with an increased number of histories sampled. Increased sampling has shown a trend of increasing the calculated dose rates. Within any reasonable history sample, it is not apparent that converged results may be obtained.

NAC has changed shielding analysis methodology for new cask designs to the ANSWERS software package containing the MCBEND code. Part of MCBEND is a 3-D biasing model that produced calculated results, for the Yankee-Rowe MPC TSC01 specific payload, approximately a factor of four higher than those measured. The sampling of the MCBEND analysis demonstrates a convergence indicative of a normal distribution for the air inlets.

SCALE/MORSE evaluations are also being re-run in an analog mode, i.e., without the code biasing. The SCALE/MORSE analog Monte Carlo evaluation is expected to produce results similar to those of the MCBEND evaluation. Completed end-fitting and neutron calculations support this expectation.

The underprediction of the air inlet dose rates for the NAC-MPC system has no safety impact, since the inlet surface represents less than 1% of the cask surface and, therefore, has no significant impact on the total cask surface fluence (which represents the driver for the site boundary analysis). Further measurements of the Yankee Rowe NAC-MPC TSC01, which produced the highest calculated air inlet dose rates using the MCBEND evaluation, provide a clear indication that the 72.104 and 72.106 evaluations are not affected.

While one-dimensional dose rate scaling was not employed in the NAC-UMS® shielding evaluations, the SAS4 sequence, with biasing, was employed. This made the NAC-UMS® air inlet dose rate evaluation susceptible to the same biasing issues as seen in the NAC-MPC system. Increasing the number of histories in the SCALE/MORSE evaluation for the NAC-UMS® system, significantly beyond those shown in the NAC-UMS® FSAR, results in an increase in the calculated air inlet dose rates from 7 mrem/hr to approximately 60 mrem/hr. Due to the large uncertainty in the dose rate results, this evaluation provided no assurance that measured dose rates would not exceed this calculated value. MCBEND evaluations indicate a significantly higher air inlet dose rate than those previously shown in the NAC-UMS® FSAR and those determined from the updated, increased number of SAS4 evaluation histories.

Similar to the NAC-MPC system, increased air inlet dose rates would have no safety impact due to the small air inlet surface area involved. To reduce occupational exposure associated with the air inlets on the NAC-MPC and NAC-UMS® systems and to reduce calculated air inlet dose rates for design basis spent fuel loads to values below the NAC-UMS® technical specification LCO A 3.2 2 limits, when an ISFSI licensee would not desire to implement Actions A.1 and A.2, NAC designed supplemental shields that may be inserted into the air inlets to reduce the localized dose peaks. The supplemental shields have no significant effect on the thermal performance of the NAC-UMS®.

To ensure that this SCALE/MORSE code limitation does not affect future evaluations, the use of SAS4 MORSE with biasing is being discontinued by NAC in favor of using MCBEND or analog MORSE evaluations that have been shown to produce conservative dose rate results.

(i) Dates and approximate times of discovery.

After loading the first NAC-MPC dry spent fuel storage cask at the Yankee Rowe site, cask surface dose rates were measured on June 26, 2002. The measured air inlet dose rates were higher than expected for the loaded cask based on the design basis shielding calculations. This led to a thorough review of the underlying shielding calculations. The determination that a code limitation exists was reached during the week of July 22, 2002.

(ii) The cause of the limitation.

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Air inlet dose rates determined from a three-dimensional MORSE Monte Carlo evaluation were scaled using one-dimensional dose rate results. This scaling neglected the effects of radiation by-passing the VCC base plate.

MORSE evaluations within the SCALE SAS4 structure employ a one-dimensional bias set. This biasing produces low probability, high weight, responses at the air inlet detector that may be under-sampled.

NAC-UMS®

MORSE evaluations within the SCALE SAS4 structure employ a one-dimensional bias set. This biasing produces low probability, high weight, responses at the inlet detector that may be under-sampled.

(iii) The failure mode, mechanism, and effect of the limitation.

Neglecting radiation that may by-pass the VCC base plate underestimates the total system response at the air inlets for conditions for which a significant percentage of dose rates results from radiation either scattering down through the annulus or radiation entering the top of the air inlets after passing through the cask liner.

The one-dimensional bias map produces non-normal distributed results that may underestimate air inlet surface dose rates due to under-sampling of high weight particles scattering through the inlet structure.

(iv) A list of systems or secondary functions that were also affected for failures of components with multiple functions.

None.

(v) The method of discovery of the limitation.

After loading the first NAC-MPC dry spent fuel storage cask at Yankee Rowe, cask surface dose rates were measured. The measured air inlet dose rates were higher for the loaded spent fuel than expected from design basis calculations. This led to a thorough review of the underlying calculations.

(vi) The manufacturer and model number (or other identification) of each component that failed during the event.

No components have failed. The code/methodology with the limitation to conservatively predict the dose rates at the air inlets of the NAC-UMS® and NAC-MPC systems is the SCALE software package, in particular the SAS4 sequence. The SAS4 sequence contains the MORSE Monte Carlo code, in combination with an XSDRN adjoint, biasing, tool.

(vii) The model and serial numbers of the affected spent fuel storage casks.

The SCALE SAS4 computer code limitations affect the air inlet dose rate evaluations reported in the NAC-MPC (72-1025) and NAC-UMS® (72-1015) dry cask storage systems FSARs. This limitation does not affect the safe storage of spent fuel in any of the NAC-MPC and NAC-UMS® storage casks.

(viii) The licensees that have affected spent fuel storage casks.

Three NAC-MPC spent fuel storage casks have been loaded with spent fuel at Yankee Rowe. Yankee Rowe plans to continue to use NAC-MPC casks for additional spent fuel storage.

Connecticut Yankee plans to use NAC-MPC spent fuel casks.

Maine Yankee plans to use NAC-UMS® spent fuel casks.

Arizona Public Service Company plans to use NAC-UMS® spent fuel casks at the Palo Verde Nuclear Generating Station.

Duke Power Company plans to use NAC-UMS® spent fuel casks at McGuire Nuclear Station.

(3) An assessment of the safety consequences and implications of the limitation. This assessment shall include the availability of other systems or components that could have performed the same function as the components and systems that were affected.

The non-conservative calculation of the air inlet dose rates for the NAC-MPC and NAC-UMS® cask designs does not affect the ability of the cask structures, systems, and components (SSCs) important to safety to perform their intended safety function. In addition, the non-conservative calculation of the air inlet dose rates does not create a substantial safety hazard. The calculated air inlet dose rates are compiled with the other calculated cask surface dose rates as input to an evaluation that demonstrates generically that the cask design will be able to meet 10 CFR 72.104 offsite dose limits at ISFSI sites. The air inlet surface represents less than 1% of the total VCC surface area. Although the air inlet dose rates were underpredicted, the remainder of the cask surface dose rates were conservatively predicted, and the compilation of all surface dose rates, including the air inlet dose rates, continues to be conservative and does not change the results of the 10 CFR 72.104 evaluations reported in the NAC-MPC and NAC-UMS® FSARs. Further, each ISFSI general licensee is required by 10 CFR 72.212 to perform a site-specific evaluation to assure compliance with the 72.104 limits for their ISFSI configuration and cask dose rates. Finally, each ISFSI licensee will monitor the actual site boundary dose rates to verify compliance with 10 CFR 72.104 limits.

The non-conservative air inlet dose rate calculations also had no effect on compliance with the 10 CFR 72.106 accident dose limits, or on compliance with the 10 CFR 72.236(d) requirement to provide radiation shielding to meet the 10 CFR 72.104 and 72.106 requirements. The non-conservative air inlet dose rate calculations do not affect compliance with the occupational exposure limits in 10 CFR 20 because the ISFSI general licensee would ensure compliance with the 10 CFR 20 limits by utilizing actual dose rate measurements and not the FSAR calculated design values.

The Appendix A Technical Specifications (TS) for both the NAC-MPC and NAC-UMS® CoCs contain a Limiting Condition for Operation (LCO) that identifies cask surface dose rate limits. However, a loaded cask can be stored with surface dose rates higher than the LCO limits by compliance with Actions A.1 and A.2 of the LCO to administratively verify the correct fuel loading and perform analysis to verify compliance with the radiation protection requirements of 10 CFR 20 and 10 CFR 72. Although storage of design basis fuel in a cask could have resulted in measured air inlet dose rates outside the Technical Specification LCO values because of the non-conservative air inlet dose rate calculations, an ISFSI licensee would have been able to comply with Actions A.1 and A.2 to remain in compliance with the Technical Specifications.

(4) A description of any corrective actions planned as a result of the limitation, including those to reduce the probability of similar occurrences in the future.

To assure that this code limitation does not affect future evaluations, the use of SAS4 MORSE with biasing is discontinued in favor of using MCBEND or analog MORSE evaluations that have been shown to produce conservative dose rate results. The NAC-UMS® and NAC-MPC FSARs will be updated to reflect the results of these revised analyses. These changes are expected to be implemented under 10 CFR 72.48 without requiring prior NRC approval because MCBEND is an alternate analysis methodology that has been NRC-approved for application to the type of analyses being conducted, and applicable terms, conditions and limitations for its use are satisfied. Additionally, it yields results that are conservative relative to those of the original approved analysis methodology.

(5) Reference to any previous similar limitations at the same facility that are known to the certificate holder.

None.

(6) The name and telephone number of a person within the certificate holder's organization who is knowledgeable about the limitation and can provide additional information.

Thomas C. Thompson

Director, Licensing

NAC International

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