July 13, 2012

Mr. Anthony Patko
Director, Licensing
Engineering
NAC International
3930 East Jones Bridge Road, Suite 200
Norcross, GA 30092

SUBJECT: REVISION 56 OF CERTIFICATE OF COMPLIANCE NO. 9225 FOR THE MODEL NO. NAC-LWT PACKAGE (TAC NO. L24618)

Dear Mr. Patko:

As requested by your application dated February 3, 2012, as supplemented by letters dated March 2 and May 24, 2012, enclosed is Certificate of Compliance No. 9225, Revision No. 56, for the Model No. NAC-LWT transportation package. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's Safety Evaluation Report is also enclosed.

The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471. Those on the attached list have been registered as users of the package under the general license provisions of 10 CFR 71.17 or 49 CFR 173.471.

Sincerely,

/RA/
Michael D. Waters, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9225
TAC No. L24618

Enclosures: 1. Certificate of Compliance No. 9225, Rev. No. 56
2. Safety Evaluation Report

cc w/encls. 1& 2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy

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SAFETY EVALUATION REPORT

Docket No. 71-9225
Model No. NAC-LWT
Certificate of Compliance No. 9225

SUMMARY

By application dated February 3, 2012, as supplemented by letters dated March 2 and May 24, 2012, NAC International (NAC or the applicant) requested a revision to Certificate of Compliance (CoC) No. 9225 for the Model No. NAC-LWT transportation package. NAC requested the addition of SLOWPOKE fuel as authorized contents.

This shipment is necessary to support shipments to the Savannah River Site in the U.S. The package loading operations and the established shipment schedule will be established by the U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA) Foreign Research Reactor (FRR) program.

CoC No. 9225 has been revised based on the statements and representations in the application, as supplemented, and the staff agrees that the changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

1.0 GENERAL INFORMATION

1.1 Packaging Description

The Model No. NAC-LWT is a Type B(U)F-96 radioactive material transportation package. Its current CoC (Revision 55 dated March 23, 2010 – ML100820126) allows shipment of Light Water Reactor (LWR) and research reactor fuel. The Model No. NAC-LWT package is shipped by truck, within an International Shipping Organization (ISO) container, or by railcar, as a Type B(U)F-96 package, as defined in 10 CFR 71.4.

1.2 Packaging Drawings

The applicant submitted two new licensing drawings and revised ten license drawings.

The new drawings include:

LWT 315-40-156, Rev. 3 (Sheets 1-4)	Canister Assembly, SLOWPOKE Fuel
LWT 315-40-158, Rev. 0	Legal Weight Truck Transport Cask Assembly, SLOWPOKE Fuel

The revised drawings include:

LWT 315-40-04, Rev. 12	LWT Transport Cask Lid Assembly SAR
LWT 315-40-087, Rev. 7	Canister Lid Assembly, Sealed Failed Fuel Can, TRIGA Fuel
LWT 315-40-088, Rev. 3	Canister Body Assembly, Sealed Failed Fuel Can, TRIGA Fuel
LWT 315-40-104, Rev. 6	Legal Weight Truck Transport Cask Assembly, PWR/BWR Rod Transport Canister
LWT 315-40-106, Rev. 2	MTR Plate Canister, LWT Cask
LWT 315-40-128, Rev. 4	Legal Weight Truck Transport Cask Assembly, TPBAR Shipment, Safety Analysis Report
LWT 315-40-129, Rev. 2	Canister Body Assembly, Failed Fuel Can, PULSTAR
LWT 315-40-130, Rev. 2	Assembly, Failed Fuel Can, PULSTAR
LWT 315-40-133, Rev. 2	Transport Cask Assembly, PULSTAR Shipment, LWT Cask
LWT 315-40-134, Rev. 2	Body Weldment, Screened Fuel Can, PULSTAR Fuel

The drawings were revised to incorporate the new SLOWPOKE fuel transport package arrangement requirements and to update some drawings.

1.3 Contents

By application dated February 3, 2012, as supplemented by letters dated March 2 and May 24, 2012, NAC requested a revision to authorize shipment of SLOWPOKE fuel in the currently certified Model No. NAC-LWT transportation package specified as follows:

- Include SLOWPOKE fuel elements as authorized content (up to eight canisters per cask, up to 100 undamaged and/or damaged SLOWPOKE fuel rods, including fuel pieces and debris, per canister);
- Include the shipping configuration of SLOWPOKE fuel rods loaded into 5x5 or 4x4 tube arrays or a combination thereof, with four tube arrays placed into each SLOWPOKE screened canister;

- Include the shipping configuration of up to four SLOWPOKE canisters placed in the top and upper intermediate basket modules of a 28 MTR fuel basket assembly;

- Incorporate editorial changes in the NAC-LWT Safety Analysis Report (SAR); and

- Incorporate two new license drawings and update ten license drawings with minor corrections.

2.0 STRUCTURAL REVIEW

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package structural and materials design has been described and evaluated under Normal Conditions of Transport (NCT) and Hypothetical Accident Condition (HAC) as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 2 (Structural Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

This section presents the findings of the structural and materials review for a request for authorization to approve shipment of the SLOWPOKE fuel under CoC No. 9225 for the Model No. NAC-LWT transportation package.

2.1 Description of Structural Design

The applicant requested the addition of SLOWPOKE fuel as authorized contents. There were no major structural changes associated with the request. The outer structural components of the package remain unchanged. The SLOWPOKE content is shipped in 5x5 and/or 4x4 tube array configurations. Four of these arrays are placed longitudinally within one SLOWPOKE canister, for a maximum of a hundred fuel rods per canister. The SLOWPOKE canisters are placed within the 28 MTR basket modules, which fit inside the main package cylinder. The basket modules used for SLOWPOKE shipments are the same as previously authorized in the package for shipments of MTR fuel. Only the top two of the four basket modules along the package length are loaded, with the other two used as shoring devices. Four canisters are included in each of the loaded baskets, for a total of eight per package.

2.2 Material Properties

2.2.1

The request is to add damaged and undamaged SLOWPOKE fuel elements and SLOWPOKE fuel pieces and debris placed in aluminum Damaged Fuel Canisters (DFCs) as approved contents for transport in the Model No. NAC-LWT transportation package. “Fuel elements” in this usage are equivalent to the normal usage of the term “fuel assemblies.” In addition, minor changes in a few drawings were requested. A definition of “degraded fuel” was provided in the SAR Table 1.1-1.

The fuel elements consist of a cast rod of a homogeneous mixture of uranium aluminum (UAl) alloy clad in 6061 aluminum (Al) tubes. All the contents are placed inside the individual Al tubes. A 5x5 or 4x4 array of these tubes are held together inside of a 6061-T6 Al square canister. The canister weldment is also 6061-T6 Al. The yield strength and modulus used in the analysis of the canisters were previously checked by the staff in the review of the TRIGA fuel as authorized content and found to be acceptable. The canister is vented at both the top and bottom with stainless steel screens. The canister provides support for the content and gross particle control. The longitudinal closure of the canister is made with tack welds including at least one inch of weldment at the top and bottom of the canister. The bottom of the canister is welded and the top stainless steel (SS) canister lid is held in place by SS screws. The canisters' materials, weld specifications, and inspection procedures are noted on Drawing 315-40-156. SLOWPOKE fuel canisters are visually inspected, load tested, and the welds examined following fabrication prior to acceptance for use (SAR Sec. 7.1.14). The bottom end cap weld of the canisters undergo Penetrant Testing (PT) and Visual Testing (VT) following load testing. PT acceptance, per ASME Section III, Article NG-5350, is indicated on the drawing.

The canisters are placed in a 304 SS MTR basket. The MTR basket has been previously approved. The basket is placed in the NAC-LWT overpack. The overpack has a 304 SS body and closure lid. The inner and outer shells are XM-19 SS. The cask has a lead (Pb) gamma shield and a borated ethylene glycol and water mixture neutron shield. Since the packaging has previously been approved for transport, it was not reevaluated.

The three materials concerns that were evaluated for the SLOWPOKE fuel are: (1) Interactions of the exposed fuel with other components (Al +SS +UAl), (2) sufficient temperature margin for components during NCT, and (3) containment source terms.

2.2.1.1 Interactions of the exposed fuel with other components, (Al+SS+UAl)

The main concern is the generation of hydrogen during the corrosion of the aluminum if the cask cavity is not dried and a galvanic couple is set up between the aluminum cladding and the stainless steel in the basket. According to Section 7.1 of the SAR, the cask cavity will be inspected for residual water and dried if any is present. The canisters will be loaded dry. If water is introduced into the cavity during the dry loading due to weather conditions, the cask will be blown dry using compressed gas or air (SAR Sec. 7.1). The cavity will be evacuated to 10 torr and held at that pressure for at least 10 minutes. If the pressure has not risen by more than 5 torr over the hold time, the cavity will be deemed dry, and the cavity will be backfilled with helium (He). This procedure can be repeated if necessary. This drying method for aluminum fuel is acceptable to the staff. Using this drying procedure, no galvanic couples are expected to occur. The He backfill should prevent the occurrence of oxidation of the aluminum.

2.2.1.2 Sufficient temperature margin for components during NCT

Maximum temperatures of the cask components are given in SAR Table 3.4-27 for NCT. The components of interest were: (1) liquid neutron shield (ethylene glycol), (2) outer and inner shields (SS), (3) gamma shield [lead (Pb)], and (4) basket (304 SS) and fuel (UAl). The temperatures of the steels were too low to be of concern. The ethylene glycol was below the flash and boiling point, and the Pb was well below the melting point. The staff finds no temperature issues with these components. The creep of the Al and UAl components was evaluated under its own deadload at both the normal and accident maximum temperature for the one year maximum transport duration and found to be minimal. The staff found the maximum storage temperatures of transport to be well within the acceptable limits for the cask components.

2.2.2 Drawing Changes

The changes to drawings 315-40-087, -088, -133, and -134 changed the inspection codes from ASME Section V Article NB-5350 to ASME Section III Article NG-5350 on a number of items. Since these were non-containment seals on the seal valve, canister, fuel can or spacer tube, the changes are acceptable to the staff.

Three material changes were made on Drawing No. 315-40-04. One O-ring material was changed from SS to more specific X-750 steel. The two other changes were deletion of the material specifications and reference to the material specifications on Drawing No. 315-40-02-06. These changes are acceptable to the staff.

2.2.3 Materials Evaluation

The SAR adequately describes the materials used for Structures, Systems, and Components (SSCs) important to safety and the suitability of those materials for their intended functions in sufficient detail to evaluate their effectiveness.

The applicant had previously met the requirements of 10 CFR 71.33(a)(5)(ii), 71.43(f), and 71.47(a). Materials used for criticality control and shielding are adequately designed and specified to perform their intended function.

The material properties of SSCs important to safety will be maintained during NCT and HAC so that the spent fuel can be readily retrieved without posing operational safety problems.

The materials properties of SSCs important to safety will be maintained during all conditions of operation so the spent fuel can be safely transported within one year of loading.

The applicant has met the requirements of 10 CFR 71.43(d). The Model No. NAC-LWT package with the requested new contents employs materials that are compatible during dry spent fuel unloading operations and facilities. These materials should not degrade over time or react with one another during any conditions of transport.

2.3 General Considerations for Structural Evaluation of Packaging

In this amendment request, the applicant has only addressed the requirements of the NCT and HAC drops. Staff finds this approach acceptable given the package structure largely remains as previously licensed.

For the regulatory requirements of NCT and HAC, the MTR basket cells are analyzed considering maximum content weight of 30 lbs. The maximum weight of a fully loaded package with SLOWPOKE fuel is 49,030 lbs. The weight of SLOWPOKE contents per MTR basket cell (that is, the total weight of a SLOWPOKE fuel canister assembly) is a maximum of 25 lbs.

The applicant evaluated the effects of the SLOWPOKE fuel canister assembly components for NCT end and side 1-foot drops. Table 2.6.7-34, "Summary of Cask Drop Equivalent G Load Factors," of the SAR shows the g-loads obtained from previous evaluations in the SAR considering the maximum loaded weight of the package. For the 1-foot drops, the end drop g-load is 15.8 g and the side drop g-load is 24.3 g; however, 20 g and 25 g are conservatively assumed for end and side drops, respectively. Material properties are conservatively taken at 93.33°C (200°F), which double the regulatory requirement of 37.78°C (100°F). The applicant performed analyses by formula of the following elements: the canister weldment, canister lid, lid handle, housing, canister insert, and lid latch and plunger. The results show large margins of safety, with the minimum being 7.78 on bending stress on the canister insert. Based on the presented calculations, staff finds the package meets the regulatory requirements of 10 CFR 71.71(c)(7).

The applicant also evaluated the effects of the SLOWPOKE fuel canister assembly components for HAC end and side 30-foot drops. These evaluations included the effects of the maximum potential gaps between the fuel and canister weldment and canister insert and weldment, as well as canister weldment and cask. The minimum margin of safety is calculated as 0.04 for the lid handle under an end drop. This value shows the stresses will come exceedingly close to the allowable; however, the components evaluated are not part of the containment system. The previous evaluations of package performance under end drops show large margins of safety for the lid closure and containment systems. The staff finds that the package can still perform its containment functions under HAC when loaded with SLOWPOKE fuel, and thus complies with the requirements of 10 CFR 71.73(c)(1).

2.4 Structural Evaluation

Given the above information, staff finds that the previous analyses for MTR fuel bound the structural behavior of the package for NCT and HAC conditions and, therefore, the package, when loaded with SLOWPOKE fuel as proposed, still meets all the applicable regulatory requirements of 10 CFR Part 71.

2.5 Conclusion

The staff evaluated the structural and materials safety analysis for the packages that are loaded with the SLOWPOKE fuel. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's structural and materials analyses demonstrate that the package design meets the structural and materials safety requirements in 10 CFR Part 71.

3.0 THERMAL REVIEW

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package thermal design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 3 (Thermal Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

This section presents the findings of the thermal review for a request for authorization to approve shipment of the SLOWPOKE fuel under CoC No. 9225 for the Model No. NAC-LWT transportation package.

3.1 Description of the Thermal Design

The applicant requested new contents of up to four (4) SLOWPOKE fuel canisters each containing up to 100 undamaged and/or damaged SLOWPOKE fuel rods with a maximum decay heat load of 0.625 Watts/canister to be loaded in a previously approved MTR basket module for the Model No. NAC-LWT package.

For SLOWPOKE fuel contents, the top and upper intermediate MTR-28 basket modules for the LWT may be loaded, which represents a total of eight (8) SLOWPOKE canisters. The empty lower intermediate and bottom basket modules are installed as axial spacers. The total package decay heat for SLOWPOKE fuel contents is 5 Watts.

3.2 General Considerations for Thermal Evaluations

In the revised SAR, the applicant presented a normal condition finite element ANSYS® thermal model of the LWT package in an ISO container to analyze the effects of the SLOWPOKE contents on package component temperatures. A calculation of predicted accident condition component temperatures was also provided. The maximum heat load analyzed was 0.625 Watts for each MTR canister for a total decay heat of 5 Watts for the SLOWPOKE contents.

3.3 Evaluation under NCT

The NCT model included a half-symmetry, cross sectional, two-dimensional planar model of the LWT package with the MTR fuel basket, with the contents inside each basket slot, and the package cavity gas modeled as helium, as described in Section 3.4.1.3 of the applicant's SAR. The model captured conduction, radiation (using radiation matrix elements), and convection. A constant temperature was applied to the outer surface of the ISO container in the model, with air modeled in the interior of the ISO container. The applicant's approach for this analysis is conservative and is acceptable to the staff.

The table below presents a summary of NCT temperatures for the Model No. NAC-LWT from the analysis of SLOWPOKE fuel.

NAC LWT Cask Temperatures for Analysis of SLOWPOKE Fuel		
Normal Conditions of Transport Results		
Cask Component	**Calculated Temperature °C (°F)**	**Temperature Limit °C (°F)**
Liquid Neutron Shield	58.33 (137)	176.67 (350)
Outer Shell	57.78 (136)	85 (185)
Lead Gamma Shield	56.67(134)	315.56 (600)
Inner Shell	56.67 (134)	[1]
Basket	57.22 (135)	148.89 (300)
ISO Container	74.44 (166)	[1]
Fuel	57.78 (136)	[2]

Notes:
1. Temperature limit not provided by applicant.
2. 200°C (392°F) is the NRC acceptable maximum temperature for aluminum clad fuel to avoid assembly slumping.

The outer surface of the package during NCT is less than 85°C (185°F) and, therefore, meets the limits prescribed in 10 CFR 71.43(g); however, the applicant intends to ship the Model No. NAC-LWT package in an ISO container.

The maximum internal pressure calculations described in Section 3.4.4 of the SAR for NCT are unchanged and continue to remain within any limits for the SLOWPOKE contents.

3.4 Evaluation under HAC

For HAC, the applicant used results from the fire transient evaluated in Section 3.5.3.2 of the SAR for the MTR fuel contents to bound the SLOWPOKE fuel contents. This approach is conservative and is acceptable to the staff. Maximum component temperatures for HAC for the MTR fuel content with a 30 Watt/Element configuration are reported in Table 3.5-2 of the applicant's SAR and are summarized below:

NAC LWT Cask Temperatures for Analysis of SLOWPOKE Fuel	
Hypothetical Accident Condition Results	
Cask Component	**Calculated Temperature °C (°F)**
Inner Shell	167.78 (334)
Fuel Basket (maximum)	190 (374)
Fuel Cladding	196.11 (385)

The maximum internal pressure calculations described in Section 3.5.4 for HAC are unchanged and continue to remain within established limits for the SLOWPOKE contents.

3.5 Thermal Evaluation

Based on the staff's review of the SAR, and the additional information submitted by the applicant, the staff finds that the NAC-LWT package will continue to meet the criteria of 10 CFR Part 71 and, therefore, SLOWPOKE research reactor fuel rods may be added to the approved contents for this package, subject to the conditions set forth in the CoC.

3.6 Conclusion

The staff evaluated the thermal safety analysis for the packages that are loaded with the SLOWPOKE fuel. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's thermal analyses demonstrate that the package design meets the thermal safety requirements in 10 CFR Part 71.

4.0 CONTAINMENT REVIEW

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package containment design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 4 (Containment Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

This section presents the findings of the containment review for a request for authorization to approve shipment of the SLOWPOKE fuel under CoC No. 9225 for the Model No. NAC-LWT transportation package.

4.1 Containment Evaluation

The Model No. NAC-LWT remains leaktight as previously evaluated. Since the package remains leaktight, no containment source terms were provided or required. There are no changes in the containment boundary.

4.2 Conclusion

The staff evaluated the containment safety analysis for the packages that are loaded with the SLOWPOKE fuel. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's containment analyses demonstrate that the package design continues to meet the containment safety requirements in 10 CFR Part 71.

5.0 SHIELDING REVIEW

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package shielding design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 5 (Shielding Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

This section presents the findings of the shielding review for a request for authorization to approve shipment of the SLOWPOKE fuel under CoC No. 9225 for the Model No. NAC-LWT transportation package.

NAC submitted an application for an amendment to the Model No. NAC-LWT transportation package CoC to incorporate SLOWPOKE spent fuel as approved contents for transport. The application also includes a number of editorial changes to the SAR and drawings.

The NAC-LWT system has previously been approved to transport light water reactor (LWR) assemblies as well as high and low enriched research reactor fuel.

This evaluation is based on the consolidated SAR Revision 41 dated April 2010 and the changes described in the SAR Revision LWT-12A dated February 3, 2012, and supplements.

5.1 Description of the Shielding Design

5.1.1 Packaging Design Features

The staff reviewed the general information chapter in the SAR, as well as the additional information on the shielding design in Chapter 5 of the SAR, "Shielding." The staff determined that all figures, drawings, and tables describing the shielding features are sufficiently detailed to support an in-depth evaluation. The shielding design features of the NAC-LWT package include multi-walled shielding materials that completely surround the fuel. This includes stainless steel and lead for gamma shielding and a neutron shield tank containing a water/ethylene glycol mixture and boron for neutron shielding.

5.1.2 Codes and Standards

The SAR identifies the appropriate regulations in 10 CFR Part 71 throughout Section 5. The staff also verified that the SAR appropriately states that the ANSI/ANS 6.1.1 1977 version for the flux to dose rate conversion factors was used. The staff finds this acceptable because this is in accordance with the guidance in NUREG-1617. In addition, the NAC-LWT package has a quality assurance program that satisfies the provisions of Subpart H of 10 CFR Part 71. In accordance with the requirements of 10

CFR 71.37(a), the approved quality assurance program has been applied to the design, analysis, package fabrication, assembly, testing, maintenance, and repair or modification of the NAC-LWT package.

5.1.3 Summary Table of Maximum Radiation Levels

The staff examined the summary tables for the Model No. NAC-LWT package with SLOWPOKE fuel in Tables 5.3.20-8 and 5.3.20-9 of the SAR. The staff reviewed these tables to ensure that the NAC-LWT package meets the requirements in 10 CFR 71.47 and 10 CFR 71.51. Since the SAR states that the NAC-LWT package will be operated under “exclusive use,” the staff verified that the evaluated radiation levels do not exceed those specified in 10 CFR 71.47(b).

The staff verified that the summary table states that the limit of 200 mrem/hr will not be exceeded on the external surface of the package. The highest calculated dose rate on the surface is 0.14 mrem/hr. This meets the regulatory limits in 10 CFR 71.47(b)(1).

The staff verified that the summary table states that the limit of 10 mrem/hr will not be exceeded at any point 2 meters from the outer lateral surface of the vehicle. The highest calculated dose 2 meters from the vehicle is 0.002 mrem/hr. The staff finds that this meets the requirement in 10 CFR 71.47(b)(3).

The staff verified that the summary table states that the external radiation dose during HAC does not exceed 1 rem/hr at 1 meter from the external surface of the package. The highest calculated dose for HAC at 1 meter from the package is 0.02 mrem/hr. The staff finds that this meets the requirement of 10 CFR 71.51(a)(2).

5.2 Source Specification

The applicant is adding up to 800 SLOWPOKE undamaged and/or damaged fuel rods contained in up to eight SLOWPOKE fuel canisters to the NAC-LWT package. The fuel rods will be loaded into 4x4 or 5x5 tube arrays with four tube arrays placed in each screened SLOWPOKE canister. A maximum of eight SLOWPOKE canisters may be loaded into two MTR-28 basket modules limited to the top two (of 4 total) axial modules. The two lower axial basket modules will not be loaded with fuel and spacers will be installed. There are seven cells in each basket module. The center row of three cells of each basket module will be blocked so that fuel canisters cannot be loaded in those locations.

SLOWPOKE fuel rods are composed of highly enriched (>90%) uranium-alloy fuel meat with aluminum cladding. Characteristics of the fuel rods are given in Table 1.2.3-14 of the SAR. Table 5.3.20-1 of the SAR gives the characteristics used in the shielding analysis. The staff verified that these parameters are consistent with those listed in Table 1.2.3-14.

The applicant determined the source term for the fuel and fuel assembly hardware using the TRITON code as part of the SCALE 6.1 code package. TRITON is a control module within the SCALE code system that enables depletion calculations to be performed by coordinating iterative calls between the cross-section processing code, NEWT, and the ORIGEN-S point depletion code. NEWT is a transport theory based code used to calculate weighted burnup-dependent cross sections that are employed to update

ORIGEN-S libraries and to provide localized fluxes used for multiple depletion regions. The TRITON sequence, based on the NEWT arbitrary-geometry transport solver, is able to perform 2-D lattice calculations for non-traditional lattice designs, including hexagonal arrays, even nonirregular lattice configurations, and non-lattice configurations.

NRC has supported development of the TRITON code for licensing. It is widely used and benchmarked for LWR spent nuclear fuel depletion. Although TRITON has not been benchmarked using SLOWPOKE fuel material, the staff finds that it is acceptable for use in this application, given the low source terms generated. The staff does not find that the uncertainty in generating the source term for this fuel type would cause the package to exceed regulatory dose rate limits. TRITON has also been listed among the codes acceptable for use in generating source terms in NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages," May 2003. Due to the above reasons, the staff finds use of this code acceptable for licensing SLOWPOKE fuel in the NAC-LWT package.

The applicant is using a 238 group library composed of ENDF/B-VII cross sections. This is the latest available and a widely used industry accepted cross section set. NUREG/CR-6802 states that the latest available version of these cross sections is recommended. Based on the above reasons, the staff finds that this cross section set is appropriate. NUREG/CR-6802 also recommends the selection of a 44 group library. Since 238 groups will calculate a more detailed and accurate source term, the staff found its use acceptable.

The SLOWPOKE reactor has a fixed Beryllium reflector surrounding the radial extent and at the bottom of the core. The top Beryllium reflector is manipulated to maintain a critical configuration. The applicant was able to adjust the fuel rod pitch to get a critical configuration to burn the fuel. Only the radial reflector was modeled to obtain the source term due to limitations of the TRITON code in the 2-D evaluation.

The applicant gives the reactor operating conditions assumed for the fuel when generating the source terms in Table 5.3.20-2 of the SAR. The applicant used conservative analysis parameters such as reduced enrichment, increased fuel mass, and increased irradiation time. All of these effects cause the source term to be artificially higher than it would realistically be, which adds additional safety margin into the calculation. Therefore, staff found this approach acceptable.

5.2.1 Gamma Source

The staff verified that the applicant specified the gamma source term as a function of energy for the fuel per metric tons uranium (MTU) in Table 5.3.20-4 of the SAR. The applicant did not analyze the source term for any fuel hardware. The staff finds this acceptable because the rods will be stored individually (without any associated hardware) in the SLOWPOKE fuel canisters. Therefore, there is no source term due to the hardware present.

The staff reviewed the energy group spectra of the gamma source to determine if it is appropriate. The applicant grouped the source term into 18 energy bins. This 18 group gamma source term has been used widely in shielding calculations. The staff reviewed the group structure and finds that it meets the recommendations in Section 3.3.3.3 of NUREG/CR-6802 and therefore found it acceptable.

5.2.2 Neutron Source

The staff verified that the applicant specified the neutron source per MTU as a function of energy. This is listed in Table 5.2.20-3 of the SAR.

The staff reviewed the energy group spectra of the neutron source to determine if it is appropriate. The applicant grouped the source term into 27 energy bins. This 27 group neutron source term has been used widely in shielding calculations and the staff found that it provides enough detail to adequately represent the source.

The applicant used the MCNP code for the shielding calculation, and the sub-critical multiplication was accounted for by the code, which is acceptable.

5.3 Model Specification

The staff reviewed Section 2 (Structural Evaluation) and 3 (Thermal Evaluation) of the SAR to determine the effects of NCT and HAC on the packaging and its contents. Section 5.3.20.2 of the SAR has a summary of the NAC-LWT cask features assumed during NCT and HAC. For NCT the applicant includes the radial neutron shield and shield shell and the impact limiters with reduced dimensions.

Chapter 2 of the SAR shows that NCT tests required by 10 CFR 71.71 do not impact the geometry of the cask. However the impact limiters experience some crush and deformation, which is why the applicant truncates the dimensions of the impact limiters. The staff verified the amount of displacement shown in Table 2.6.7-32 and found that the effects of the NCT tests are bounded by the dimensions assumed in the model. The staff found that the shielding model is consistent with the effects of the tests performed in compliance with 10 CFR 71.71.

Under HAC the applicant does not include the upper and lower impact limiters as part of the shielding model. The applicant does not include the radial neutron shield and shell. The applicant did not include the effects of lead slump from the 30-foot drop. The staff reviewed the shielding calculation for TRIGA fuel (a previously approved content), and the dose rate at 1 meter from the package due to HAC (including lead slump) is about 200 mrem/hr. TRIGA fuel gives a significantly larger source term than the SLOWPOKE fuel (1.05 kW per package versus 5 Watts for SLOWPOKE fuel). The HAC dose rate at 1 meter for SLOWPOKE fuel is 0.02 mrem/hr (without considering lead slump).). In addition, the staff performed some scoping calculations and found that the entire bounding source term from SLOWPOKE fuel allowed within the NAC-LWT concentrated into a small volume, that is unrealistic for the contents to actually reconfigure to, placed near the side of the cask, with no lead shielding, is capable of meeting HAC regulatory dose rates. Therefore, the staff found that the NAC-LWT package with SLOWPOKE fuel is bounded by shielding calculations for previously approved contents and will meet the regulatory dose rate limits for HAC in 10 CFR 71.51(a)(2) of 1 rem/hr at 1 meter from the package surface.

5.3.1 Configuration of Source and Shielding

The staff examined the dimensions used in the shielding model as described by Tables 5.3.20-1 and 5.3.20-7 of the SAR. The staff verified that the dimensions were consistent with the cask drawings presented in Section 1.4 of the SAR. The applicant used nominal dimensions for modeling the cask. The staff found this acceptable given the dose rates that are calculated with the SLOWPOKE fuel are low and have a large margin to regulatory limits. In all models, the cask and canister shield thicknesses and axial extents are explicitly represented, as well as a detailed representation of the basket structural members, base plates and support plates.

The fuel is homogenized within the canister tubes. The staff found this acceptable because Section 5.5.3.1 of NUREG-1617 states that fuel materials may be homogenized to facilitate shielding calculations. The fuel tubes are modeled explicitly as 5x5 tube arrays and are modeled within the appropriate exterior basket locations.

The applicant assumed a uniform axial burnup profile in the shielding dose rate calculation. The staff found this acceptable because of conservative assumptions in the analysis, such as using the source term from a rod in the center of the core that produces the highest source term. This is conservative because no single rod would exceed this source term, and realistically, most of the other rods will produce a lower source term. In addition, the rods will be arranged in 5x5 arrays stacked two high, which will spread the source out uniformly along the area where the contents are loaded. Also, the dose rates that are calculated with the SLOWPOKE fuel are low and have a large margin to regulatory limits. The staff has reasonable assurance that any uncertainties related to axial peaking due to the burnup profile will not cause the cask to exceed any regulatory limits.

Although the SLOWPOKE fuel rods may be damaged, aluminum metallic fuel will not disperse through the canister. In addition, the fuel rods will be placed into individual tubes. Because of these reasons, the applicant's model is applicable to both intact and non-intact fuel.

Although the application states that the NAC-LWT package is to be shipped by exclusive use, dose rates meet regulations for non-exclusive use. Therefore, the applicant did not include dimensions of the transport vehicle. Since this assumption gives higher dose rates, because they are being calculated closer to the package, the staff found this acceptable.

The staff verified that the dose point locations include all locations prescribed by 10 CFR 71.47(a) and 71.51(a)(2). These points include the package surface and 1 meter from the package surface. Although the package meets the dose rates prescribed in 10 CFR 71.47(a), the applicant additionally provided dose rate calculations that meet the locations specified in 10 CFR 71.47(b) for the transportation vehicle edge, 2 meters from the transportation vehicle edge, and the normally occupied space of the transportation vehicle. These are all summarized in Table 5.3.20-8 of the SAR. Two-dimensional plots showing how the dose rate varies axially are shown in Figures 5.3.20-7 through 5.3.20-9 of the SAR. The highest dose rate is near the top of the cask where the lead shielding is tapered. The values reported in Table 5.3.20-8 agree with those in Figures 5.3.20-7 through 5.3.20-9.

The applicant's model includes the streaming that is possible above the lead shield and has explicitly modeled the tapering of the lead shield near the top of the cask. The staff found that the applicant has addressed streaming effects.

5.3.2 Material Properties

The NAC-LWT package is made of stainless steel, lead, and a neutron shield tank containing a water/ethylene glycol mixture and boron for neutron shielding. The staff verified that the applicant identified the materials and mass densities of the homogenized fuel rods, shield and structural materials, and impact limiter. These are specified in Tables 5.3.20-5 and 5.6.20-6 of the SAR. The staff found that the values used are typical values for the commonly used materials and are reasonable for use in the shielding analysis. The shielding properties of these materials would not degrade for the life of the packaging because they are not sensitive to radiation degradation.

The applicant assumes the neutron shield tank is voided for HAC. Therefore, the staff found that the applicant has appropriately addressed the effect temperature has on this material.

5.4 Evaluation

5.4.1 Methods

For the shielding analysis, the applicant uses the MCNP5 code, Version 1.30. Cross section tables used in the MCNP analysis are the default provided in the MCNP5 1.30 distribution and draw on mcplib04 for gamma analyses and isotope dependent data from actia, rmccs, or t16_2003 data for neutron analyses. MCNP is a three dimensional code that employs the Monte Carlo method. It is widely used and recognized for shielding analyses and mentioned in NUREG-1617 as an acceptable code for use in shielding evaluations involving spent fuel. The staff found that its use is acceptable for this application.

5.4.2 Key Input and Output Data

The staff verified that key input data for the shielding calculations are identified, and that information about the source and shielding were properly input into the codes by examining the input file provided by the applicant. The staff verified that proper convergence was achieved from the calculation by reviewing an output file and that the calculated radiation levels in the output file agree with the radiation levels reported in the SAR.

5.4.3 Flux-to-Dose-Rate Conversion

The SAR states that the shielding evaluation uses the ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors in all the cask shielding evaluations. The staff found the use of these conversion factors acceptable because they are recommended for use in shielding evaluations by NUREG-1617.

5.4.4 Radiation Levels

The staff reviewed the calculated radiation levels as displayed in Figures 5.3.20-7 through 5.3.20-9 of the SAR. The staff confirmed that the calculated radiation levels under both NCT and HAC for undamaged and damaged fuel are in agreement with Tables 5.3.20-8 and 5.3.20-9 in the SAR, and that they satisfy the limits in 10 CFR 71.47(a) and 10 CFR 71.51(a)(2). The staff verified that the analysis showed that the locations selected are those of maximum radiation levels and include radiation streaming paths.

The staff also verified that the applicant's evaluation addresses damage to the shielding under NCT and HAC.

5.4.5 Confirmatory Analysis

Due to the low radiation levels calculated for this fuel type, the staff did not perform a confirmatory analysis. The staff expects that the source term would be low for this fuel type given factors such as low core power, low mass, and low burnup.

5.4.6 Evaluation Findings

Based on the staff's evaluation above of the Model No. NAC-LWT, the staff has the following evaluation findings for the addition of SLOWPOKE fuel:

- As documented in Section 5.1 of this SER, the staff found that the package description and evaluation satisfied the shielding requirements of 10 CFR Part 71.

- As documented in Section 5.2 of this SER, the staff found that the source specification used in the shielding evaluation was sufficient to provide a basis for evaluation of the package against the shielding requirements of 10 CFR Part 71.

- As documented in Section 5.3 of this SER, the staff found that the models used in the shielding evaluation were described in sufficient detail and permitted an independent review of the package shielding design.

- As documented in Section 5.4.4 of this SER, the staff found that the external radiation levels satisfy the requirements of 10 CFR 71.47 for packages transported by an exclusive-use vehicle.

- As documented in Sections 5.3 and 5.4 of this SER, the staff found that the radiation levels will not significantly increase during NCT consistent with the tests specified in 10 CFR 71.71.

- As documented in Sections 5.1.3 and 5.4 of this SER, the staff found that the maximum external radiation level at one meter from the external surface of the package will not exceed 1 rem/hr during HAC consistent with the tests specified in 10 CFR 71.73

5.5 Conclusion

The staff evaluated the shielding safety analysis for the packages that are loaded with the SLOWPOKE fuel. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's shielding analyses demonstrate that the package design meets external radiation standards in 10 CFR Part 71.

6.0 CRITICALITY REVIEW

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package criticality safety design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 6 (Criticality Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

This section presents the findings of the criticality review for a request for authorization to approve shipment of the SLOWPOKE fuel under CoC No. 9225 for the Model No. NAC-LWT transportation package.

6.1 Description of Criticality Design

6.1.1 Packaging Design Features

Staff reviewed both the general information chapter in the SAR and the information presented in the criticality safety chapter. Staff determined that the description of the criticality safety features supporting their evaluation, including the figures, drawings, and tables, as modified based on the applicant's response to the request for additional information, provide enough detail to allow for an in-depth evaluation.

The proposed design allows for up to 800 intact SLOWPOKE rods (or its equivalent in damaged fuel rods in fuel canisters) to be transported in a NAC-LWT cask.

6.1.2 Codes and Standards

The SAR appropriately identifies the regulations in 10 CFR Part 71 throughout all of Chapter 6.

6.1.3 Summary Table of Criticality Evaluations

Staff reviewed the summary tables for the SLOWPOKE fuel in Tables 6.7.2-8 and 6.7.2-9 of the SAR to ensure that the Model No. NAC-LWT will continue to meet the requirements in 10 CFR Part 71. In all instances, the calculated reactivity results were all well below the administrative k_{eff} +2σ limit of 0.95, with the highest calculated reactivity found to be 0.5706 for the damaged fuel under HAC.

6.2 Fissile Material Contents

SLOWPOKE rods contain highly enriched uranium in an aluminum matrix material, clad in aluminum. The uranium enrichment analyzed in the criticality model is 95 wt.% ^{235}U, with a total mass per rod of 2.8 grams. Characteristics of the actual fuel rods are provided by the applicant in Table 6.7.2-1 of the SAR.

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configuration

The configuration proposed for the NAC-LWT would allow up to 800 SLOWPOKE undamaged and/or damaged rods contained in up to eight fuel canisters. The fuel rods can be placed into either 4x4 or 5x5 tube arrays, with four tube arrays placed in each SLOWPOKE canister, where it's screened to prevent gross material from escaping the canister. The filled canisters are placed into one of the four outer openings of the MTR-28 basket configuration. Since there are seven cells in each basket, the center row of three cells on each basket are blocked to prevent fuel canisters from being loaded into these positions. Only the top two baskets are loaded, resulting in a maximum of eight SLOWPOKE canisters per package. The bottom basket modules are not loaded and are used as spacers.

6.3.2 Material Properties

Staff verified that the applicant identified all relevant material properties of the SLOWPOKE fuel. This information was provided in Table 6.7.2-3 of the SAR and is based on the fuel configuration and subsequent modeled fuel configuration provided in Tables 6.7.2-1 and 6.7.2-2, respectively.

6.3.3 Computer Codes and Cross Section Libraries

The applicant used the MCNP5 code package with the ENDF/B-VI cross-section library to develop their models to support the evaluation of the SLOWPOKE payload in the Model No. NAC-LWT cask.

6.3.4 Demonstration of Maximum Reactivity

For the criticality evaluation of both NCT and HAC conditions of undamaged fuel, the maximum reactivity configuration was determined through a series of studies of various potential conditions of the package, using an initial assumption that the accident conditions with close pitch and flooding of the canister interior would be the most bounding, based on the applicant's preliminary calculations and their experience with other MTR basket payloads. These studies included geometric perturbations, material tolerances, moderator density, and preferential flooding. The results of these analyses indicated that the bounding conditions for the SLOWPOKE fuel in the NAC-LWT package were with the fuel rods pitch reduced in a flooded canister with the fuel shifted away from the center of the 5x5 array.

The applicant also requested the ability to transport damaged fuel in the form of gross fuel material. As illustrated by the studies performed by the applicant in the undamaged scenarios, the reactivity is maximized with a dry cask cavity and a flooded canister interior. Since the fuel rods are replaced by a water/fuel mixture in the damaged scenarios, a rod shift is not applicable. This configuration led to an increase in the maximum reactivity of approximately 10% above the undamaged fuel.

6.3.5 Confirmatory Analyses

Staff created models of the SLOWPOKE fuel in both the undamaged and damaged fuel configurations using the information provided by the applicant regarding the material compositions and geometric configuration. Staff used the SCALE6 system of codes and the v7-238 cross section library to confirm that the results for the bounding cases calculated by the applicant using MCNP were reasonable. In all instances, staff results agreed closely with those cited by the applicant, and in all calculations, the maximum calculated k_{eff} +2σ's were well below the applicant's Upper Safety Limit (USL) of 0.9171.

6.4 Single Package Evaluation

SLOWPOKE fuel consists of an axial stack of four canister inserts each containing a 5x5 fuel tube array, which equates to 100 rods per canister. The canister is placed into one of the outer four openings of the MTR-28 basket configuration. Only the top two baskets are loaded, with the bottom two baskets serving as spacers only. This loading configuration allows for up to 800 intact SLOWPOKE rods or its damaged equivalent to be loaded into the NAC-LWT cask, and is subjected to full water reflection. The applicant only evaluated the 5x5 array, with the justification that while the 4x4 array configuration does allow for increased moderation, the reduction of fissile material by ~36% will make the system much less reactive. Staff agrees with this assessment.

6.5 Evaluation of Package Arrays under NCT

For the NCT cases, the impact limiter diameter is modeled as identical to the neutron shield tank diameter, which effectively allows for a closer packed cask array than would be physically possible if the impact limiter diameter was used, and is a conservative assumption. Reflecting boundary conditions were used on all sides of the cask to simulate an infinite array. Enrichment was assumed to be 95 wt.% ^{235}U. Based on these bounding conditions, the maximum k_{eff} +2σ calculated by the applicant was 0.3571 for NCT undamaged fuel. For the damaged fuel configuration, the maximum k_{eff} +2σ calculated by the applicant was found to be 0.3842. Both of these values are significantly below the USL for this package.

6.6 Evaluation of Package Arrays under HAC

Similar to the evaluation for NCT, the NAC-LWT cask under HAC analysis used the bounding conditions identified above, including the removal of the neutron shielding well as the neutron shield tank and the cask impact limiters. Based on this configuration, the maximum k_{eff} +2σ for an infinite array of packages containing undamaged fuel was calculated by the applicant to be 0.5222. For damaged fuel in the same configuration, the maximum k_{eff} +2σ for an infinite array of packages was calculated by the applicant to be 0.5706. Both of these values are significantly below the USL for this package.

6.7 Benchmark Evaluation

Although the evaluated enrichment of the maximum reactivity case for the SLOWPOKE fuel is slightly above the benchmark evaluated for the research reactor benchmark evaluation performed in Section 6.5.5 of the SAR (95 wt.% for SLOWPOKE vs. 93.2 wt.% in the critical set), the maximum reactivity Energy of the Average neutron Lethargy Causing Fission (EALCF) of 0.08eV is within the area of applicability, and the applied USL of 0.9171 based on the EALCF, bounds the use of this fuel.

6.8 Burnup Credit

Burnup credit is not used in the evaluation of SLOWPOKE fuel in the NAC-LWT package.

6.9 Evaluation Findings

The staff evaluated the criticality safety analysis for the packages that are loaded with SLOWPOKE fuel and has the following evaluation findings:

- Staff found that the NAC-LWT package description and evaluation for the addition of SLOWPOKE fuel provided an adequate basis for the criticality evaluation.
- Staff found that the description of the SLOWPOKE fissile material contents provided an adequate basis for the criticality evaluation.
- Staff found that the criticality description and evaluation of the Model No. NAC-LWT package with SLOWPOKE fuel contents addresses the criticality safety requirements of 10 CFR Part 71.
- Staff found that the criticality evaluation of a single package is subcritical under the most reactive credible conditions.
- Staff found that the criticality evaluation of the most reactive infinite array was subcritical under NCT.
- Staff found that the criticality evaluation of the most reactive infinite array was subcritical under HAC.
- Staff found that the benchmark evaluation of the calculations were appropriate for the evaluation of SLOWPOKE fuel contents in the NAC-LWT package.
- Staff found that burnup credit was not used in the evaluation of the SLOWPOKE fuel contents.
- Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's criticality analyses demonstrate that the package design meets the criticality safety requirements in 10 CFR Part 71.

6.10 Conclusion

The staff evaluated the criticality safety analysis for the packages that are loaded with the SLOWPOKE fuel. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's criticality analyses demonstrate that the package design meets the criticality safety requirements in 10 CFR Part 71.

7.0 PACKAGING OPERATIONS REVIEW

The staff reviewed Chapter 7 of the SAR in the application to revise the Model No. NAC-LWT package to verify that it meets the requirements of 10 CFR Part 71 and is adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

The chapter includes the procedures for package loading, unloading, and preparation of the empty package for transport. To support this revision request, Sections 7.1.13 and 7.1.14 of the SAR were added to include the procedures for loading of the SLOWPOKE fuel. Sections 7.2.3

and 7.2.4 were revised to include procedures for unloading the SLOWPOKE fuel. Other clarifying changes were also made to Chapter 7.

The staff reviewed and evaluated the proposed loading and unloading procedures of the SLOWPOKE fuel. Based on the statements and representations in the application, the staff concludes that the package operations meet the requirements of 10 CFR Part 71, and that they are adequate to assure the package will be operated in a manner consistent with its evaluation for approval. Further, the CoC is conditioned to specify that the package must be prepared for shipment and operated in accordance with the Operating Procedures in Chapter 7 of the application.

8.0 ACCEPTANCE TESTS AND MAINTENANCE REVIEW

To support this revision request, no changes were made to Chapter 8 of the SAR. The staff concludes that the package continues to meet the requirements of 10 CFR Part 71.

CONDITIONS

In addition to the new and revised drawings in Condition 5.(a)(3)(ii), the following changes have been made to the Certificate:

Condition 3.(b) was changed to add the new consolidated application date.

Condition 5.(b)(1)(viii) was added to specify the type and form of the SLOWPOKE fuel.

Condition 5.(b)(2)(xix) was added to specify the quantity of SLOWPOKE fuel authorized.

Condition 5.(c) was modified to specify the CSI for the SLOWPOKE fuel.

Condition 6. was modified to add the SLOWPOKE fuel.

Condition 14. was modified to change the Drawing revision number.

Condition No. 19 was changed to allow the use of Revision 55 of the certificate for approximately one year.

CONCLUSION

CoC No. 9225 has been revised to authorize shipment of SLOWPOKE fuel as specified above in the Model No. NAC-LWT package. Based on the statements and representations in the application, and with the conditions listed above, the staff agrees that this authorization does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued on <u>July 13, 2012</u>.