UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT
Docket No. 71-9225
Model No. NAC-LWT
Certificate of Compliance No. 9225
Revision No. 65

SUMMARY

By application dated February 25, 2015 (see Agencywide Documents Access and Management System (ADAMS) Accession No. ML15072A378, as supplemented on June 5 (see ADAMS Accession No. ML15170A106), 17 (see ADAMS Accession No. ML15170A0500), and 19, 2015 (see ADAMS Accession No. ML15174A138), NAC International (NAC or the applicant) requested a revision to Certificate of Compliance No. 9225 for the Model No. NAC-LWT (NAC-LWT) transportation package. NAC requested adding a SLOWPOKE fuel core as authorized contents. The U.S. Nuclear Regulatory Commission (NRC) staff performed its review of the application as supplemented using the guidance in NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

Based on the statements and representations in the application, as supplemented, the NRC staff agrees that these changes do not affect the ability of the package to meet the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 GENERAL INFORMATION

1.1 Packaging Description

The NAC-LWT package is a Type B(U)F-96 radioactive material transportation package. It is authorized to transport several types of contents, including light-water reactor spent fuel, research reactor spent fuel, and high enriched uranyl nitrate liquid in containers specifically designed for the liquid. The NAC-LWT package is shipped by truck, boat, or railcar and depending on the content, within an international shipping organization (ISO) container.

1.2 Packaging Drawings

The applicant submitted three drawings that show the basket design to transport the SLOWPOKE fuel core, and its configuration within the NAC-LWT package.

The revised drawings include:

LWT 315-40-185, Rev. 0	LWT Transport Cask Assembly, SLOWPOKE Contents
LWT 315-40-186, Rev. 2	Fuel Core Basket Assembly, SLOWPOKE
LWT 315-40-187, Rev. 1	Basket Lid Assembly, SLOWPOKE

1.3 Contents

NAC requested a revision to authorize shipment of a single SLOWPOKE fuel core in the NAC-LWT package specified as follows:

A single undamaged SLOWPOKE fuel core is loaded into a SLOWPOKE basket. The SLOWPOKE fuel core contains up to 298 fuel rods, upper and lower plates and the center tube. A single loaded SLOWPOKE basket, is accompanied by intermediate MTR-42 baskets and a bottom MTR-42 basket, such that the SLOWPOKE basket is adjacent to the NAC-LWT lid, as shown in NAC Drawing No. LWT 315-40-185.

The SLOWPOKE fuel core has the following parameters:

Parameter	Limiting Value
Maximum Cask Heat Load (W)	45
Maximum Weight of Contents (lb)	15
Maximum Number of Fuel Rods per Core	298
Maximum Initial ^{235}U per Rod (g)	2.83
Maximum Initial Enrichment (wt% ^{235}U)	95.3
Maximum Initial ^{235}U per core (g)	837
Minimum Initial Enrichment (wt% ^{235}U)	90
Minimum Cool Time	2 Weeks
Maximum Core Average Depletion (% ^{235}U)	2.1%

2.0 STRUCTURAL EVALUATION

The staff reviewed the application to revise the Model No. NAC-LWT package to verify that the package structural design has been adequately described and evaluated under normal conditions of transport and hypothetical accident conditions as required in 10 CFR Part 71. The staff also reviewed the application to determine whether the package fulfills the acceptance criteria listed in Section 2, “Structural Review,” of NUREG-1617.

This section presents the findings of the structural review for a request for authorization to approve shipment of the SLOWPOKE fuel core under Certificate of Compliance No. 9225 for the NAC-LWT package. The staff limited the scope of the structural review to the areas of the safety analysis report that are affected by the change to the spacer which include the free drop evaluations for both normal conditions of transport and hypothetical accident conditions, adequacy of the lifting lugs, and the material specification changes.

2.1 Description of Structural Design

The applicant requested the addition of SLOWPOKE fuel core as authorized contents. The outer structural components of the packaging remain unchanged. Per the applicant, one SLOWPOKE fuel core will be loaded into a SLOWPOKE basket. As per the application, NAC-LWT safety analysis report (SAR), revision LWT-15A, dated February 2015, the SLOWPOKE fuel core primary components are up to 298 undamaged SLOWPOKE fuel rods, a center tube, and upper and lower plates. SLOWPOKE fuel rods are composed of highly enriched uranium-aluminum alloy fuel meat within aluminum alloy A1 1100 cladding. One SLOWPOKE fuel core will be transported in the NAC-LWT. A spacer is attached to the SLOWPOKE basket lid locating the fuel core at the bottom of the basket. The basket is

transported with four empty intermediate and one bottom MTR-42 basket modules used as spacers between the SLOWPOKE basket and the bottom forging of the NAC-LWT package to provide axial spacing. The SLOWPOKE fuel core basket is therefore located next to the NAC-LWT cask lid. The axial stack up of the basket, lid assembly and spacer leaves an axial gap of 9.8 inches between the end of the spacer assembly and the top of the basket base plate for the SLOWPOKE fuel core assembly. The staff has reviewed the package structural design description and concludes that the contents of the application meet the requirements of 10 CFR 71.31.

2.2 Materials Evaluation

The NAC-LWT SLOWPOKE package description is discussed in Section 2 of the application. The principal structural members of the NAC-LWT SLOWPOKE fuel core basket assembly are Type 304 stainless steel (SS). A comprehensive list of assembly components are listed as follows:

- Basket Weldment
  - Base Plate
  - Top-Annular Ring
  - Mid-Annular Ring
  - Guide Bar
  - Guide Pin
  - Mesh Retainer
  - Mesh
  - Threaded Inserts
- Basket Lid Assembly Weldment
  - Base Plate
  - Lid Collar
  - Collar Cover Plate
  - Lifting Lugs
  - Grapple Guide
  - Grapple Stop
  - Keyway Spacer
- Basket Lid Spacer Weldment
  - Mounting Plate
  - Shield Plate
  - Extension
  - Threaded Inserts

Basket Weldment

The basket weldment is fabricated from a 0.5-inch thick circular cylinder or outer shell American Society of Mechanical Engineers (ASME) SA269/SA312 with an outer diameter of 10.75-inches and 26.05-inches long. A base plate (0.5-inch thick), a 13.27-inch diameter top-annular ring (0.75-inch thick), and a 13.27-inch mid-annular ring (0.5-inch thick), all ASME SA240/SA276, all welded to the shell using a single-bevel groove. Lastly, guide bars, ASME SA276, are welded to the assembly discs using a fillet weld.

Basket Lid Assembly Weldment

A 13.3-inch diameter base plate (0.5-inch thick), constructed of ASME SA240/SA276, is the principle structural member of the lid assembly and is bolted to the basket assembly top-annular ring using six cone head bolts, Type XM-19, ASME SA479, a nitrogen strengthened austenitic SS.

Basket Lid Spacer Weldment

Fits inside the basket assembly, secures the SLOWPOKE fuel core assembly and provides shielding. A 15.75-inch long lid spacer assembly is fabricated from an 8.0-inch diameter extension or tube (0.38-inch thick), ASME SA269, a 9.5-inch diameter shield or base plate (1.5-inches thick), ASME SA240/SA276, and a 9.5-inch diameter mounting plate (2.5-inches thick), ASME SA240/SA276, with thread inserts for bolting to the lid assembly using SS socket head cap screws, ASME SA193, Grade B8S. Both the shield and mounting plates are welded to the extension using a single bevel groove joint design.

The staff reviewed the materials selected and determined that they are acceptable and provide reasonable assurance for safety of the package. Specifications and temperature dependent mechanical properties, including yield strength, tensile strength, allowable strength, modulus of elasticity, and coefficient of thermal expansion conform to the ASME Boiler and Pressure Vessel (B&PV) Code, Section II, Part D.

2.2.1 Chemical or Galvanic Reactions

, During normal conditions of transportation, the NAC-LWT packaging with SLOWPOKE content internals will not be subject to continuous or frequent exposure to moisture and that water intrusion is not likely to occur. Further, the entire assembly is fabricated from SS predominately Type 304, therefore galvanic potential is not a concern. The staff concludes that, to the maximum credible extent, there are no significant chemical, galvanic or other reactions among the packaging components, among package contents, or between the packaging components and the contents in dry or wet environment conditions.

2.2.2 Effects of Radiation on Materials

Austenitic stainless steel was chosen, in part, for the construction of the package due to desirable corrosion characteristics and as a durable material service proven to withstand the damaging effects from radiation. Therefore, the staff finds that radiation effects is not a concern.

2.2.3 Brittle Fracture

All the structural components of the package are fabricated from austenitic SS which is ductile at low temperatures. Regulatory Guide 7.11, “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)” states austenitic SS is not susceptible to brittle facture at temperatures encountered in transport.

The staff finds since this material does not undergo an abrupt ductile-to-brittle transition in the temperature range of interest (- 40ºC), it is safe from brittle fracture.

2.3 Lifting and Tie-down Standards for All Packages

The staff also reviewed Section 7.5 of the NAC Calculation Number 50026-2001, Revision 0, dated February 17, 2015, to verify the adequacy of the lifting lugs, and the lid assembly to basket assembly bolts. There are four lifting lugs attached to the lid assembly. Each lifting lug is an L shaped bracket which is welded to the lid base plate and the lid collar. The lug is attached to the lid base plate with a full penetration bevel weld and to the lid collar with a combined 1/8-inch bevel weld on one side and a 1/8-inch flare bevel weld on the opposite side. The analysis result shows acceptable margins of safety for the yield and the ultimate strength of the materials. The staff has reviewed the lifting system for the package and concludes that they meet 10 CFR 71.45 standards.

2.4 General Considerations for Structural Evaluation of Packaging

The staff reviewed the NAC calculation mentioned above, which was included in the application for this amendment request. As indicated in this calculation, the SLOWPOKE basket structural analysis is based on classical hand calculations. The weight of the entire SLOWPOKE fuel core assembly is 5,086 grams (11.21 lbs). However, in the structural evaluation the applicant used a weight of 15 lbs. for the fuel core assembly weight. As 15 lbs. is higher than 11.21 lbs, it is conservative to use for the structural evaluation. There are no other major structural changes associated with this request, and the applicant applied the same structural analysis methods as previously approved by the NRC.

The SLOWPOKE basket assembly consists of the basket weldment, lid assembly weldment and an internal spacer assembly weldment. Section 4.1 of the above mentioned calculation package shows that the maximum acceleration loads for the 1-foot side drop used by the applicant was 25g; and for the end drop was 20g.

For the 30-foot side drop the maximum acceleration loads used by the applicant were 55g; and for the end drop was 60g. No finite element or other numerical analysis techniques are used. The applicant evaluated the NAC-LWT package for the accelerations due to vibration and shock; for maximum acceleration of 5g, (bounding value for 3 standard deviations in the vertical direction, per Figure 5, of the SAND77-1110, "Shock and Vibration Environments for Large Shipping Container During Truck Transport (Part I),") for 1-foot drop for normal conditions of transport, and the accelerations due to a postulated 30-foot drop for hypothetical accident conditions as documented in the NAC-LWT safety analysis report (SAR), Revision 43, dated January 2015 (see ADAMS Accession No. ML15054A586).

The staff reviewed, Section 7.0 of the above mentioned calculation, presented in the application, and verified that the regulatory requirements of the normal conditions of transport and hypothetical accident conditions for the fuel core assembly; basket spacer assembly; basket assembly; and the lid assembly have been addressed. Based on the review, and given that the overall NAC-LWT package structure largely remains as previously approved and certified, the staff finds the approach taken by the applicant as acceptable. The stainless steel material properties and the bolting material properties are taken from the ASME B&PV Code, Section II, Part D (2010 Edition). Since the ultimate strength, yield strength, and the design stress intensity in this edition of the ASME code are lower than those used in the NAC-LWT SAR, Revision 43, this is conservative, and therefore acceptable to the staff. The staff has reviewed the packaging structural evaluation and concludes that the application meets the requirements of 10 CFR 71.35.

2.5 Normal Conditions of Transport

For the normal conditions of transport side drop and end drop, the staff's review found acceptable margins of safety, e.g., a margin of safety of 31.2 for the basket spacer assembly under the side drop; a margin of safety of 3.14 for the basket assembly under the side drop; and 1.12 for the lid assembly under the end drop conditions. The minimum margin of safety of 0.32 was for the SLOWPOKE fuel core assembly fuel pins in bending, under the side drop case, as shown in the SAR Section 2.9.5.1. The staff has reviewed the packaging structural performance under the normal conditions of transport and concludes that there will be no reduction in the effectiveness of the packaging. Based on the review of the presented calculations, staff finds the package meets the regulatory requirements of 10 CFR 71.71(c)(7).

2.6 Hypothetical Accident Conditions

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The applicant also evaluated the effects for the hypothetical accident conditions side drop and the end drop. The staff reviewed the applicant's analyses for hypothetical accident conditions and found that the margins of safety were acceptable e.g., 31.9 for the basket spacer assembly under the side drop, 19.9 for the basket assembly under the side drop, and 0.67 for the lid assembly under the end drop conditions. The minimum margin of safety as calculated by the applicant was 0.20 for the fuel core assembly fuel pins in bending, under the side drop case. This value shows the actual stresses are very close to the allowable stresses; however, since the margin of safety is greater than 0, the fuel core assembly retains its structure, and the fuel pin is not a part of the package containment system, it is found acceptable by the staff. The staff finds that the package will perform its intended functions under hypothetical accident conditions when loaded with SLOWPOKE fuel core basket, and thus complies with the requirements of 10 CFR 71.73(c)(1). The staff has reviewed the packaging structural performance under the hypothetical accident conditions and concludes the packaging has adequate structural integrity to satisfy the subcriticality, containment, shielding, and temperature requirements of 10 CFR Part 71.

2.7 Conclusion

The staff evaluated the structural and materials safety analysis for the NAC-LWT package loaded with the SLOWPOKE fuel core in the SLOWPOKE basket. The staff finds that the NAC-LWT with the SLOWPOKE core meets the regulatory requirements for mitigating galvanic or chemical reactions, is unaffected by cold temperatures and is constructed with materials and processes in accordance with acceptable industry codes and standards. 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 as described in 10 CFR Part 71.

3.0 THERMAL EVALUATION

Currently, up to four SLOWPOKE fuel canisters each containing up to 100 SLOWPOKE fuel rods with a maximum decay heat load of 0.625 Watts/canister can be loaded in a MTR basket module. The total package decay heat for SLOWPOKE fuel rods in the fuel canisters is 5 Watts. NAC has proposed adding a SLOWPOKE fuel core as authorized contents to the NAC-LWT transportation package. The staff limited the scope of the thermal review to the areas of the safety analysis report that are affected by the adding the SLOWPOKE fuel core, which include the normal conditions of transport and hypothetical accident conditions thermal calculations.

3.1 Description of the Thermal Design

For this licensing action, the applicant is requesting approval for a SLOWPOKE fuel core, with a maximum decay heat of 45 Watts, loaded in a SLOWPOKE fuel basket. The SLOWPOKE fuel core consists of fuel rods, a center tube, and upper and lower plates. SLOWPOKE fuel rods are composed of highly enriched uranium-aluminum alloy fuel meat within aluminum alloy. The staff has reviewed the package description and evaluation and concludes that they satisfy the thermal requirements of 10 CFR Part 71.

3.5 Normal Conditions of Transport

An expected bounding decay heat of 45 Watts was considered in the thermal evaluation for the SLOWPOKE fuel core which is subsequently bounded by the 1.26 kW total heat load for the materials test reactor (MTR) research reactor spent fuel contents. The applicant noted that the cask ambient conditions are the same for the SLOWPOKE fuel core as for the MTR fuel, therefore the maximum temperature of all cask body components for the SLOWPOKE contents would be bounded by the maximum cask component temperatures for the MTR fuel contents. It follows that the cask inner shell temperature for the MTR fuel contents bounds the maximum cask inner shell temperature for the SLOWPOKE fuel core configuration. The maximum package inner shell temperature was used as the boundary condition for the finite element model for the SLOWPOKE thermal evaluation. The results of the finite element analysis demonstrated that the fuel basket and fuel cladding temperatures of 239°F and 304°F, respectively, were below the values of 256°F and 363°F obtained for the MTR fuel. Furthermore, the maximum cladding temperature for the SLOWPOKE core was significantly lower than the maximum value of 472°F evaluated previously for all contents. The staff has reviewed the package design, construction, and preparations for shipment and concludes that the package material and component temperatures will not extend beyond the specified allowable limits during normal conditions of transport consistent with the tests specified in 10 CFR 71.71.

3.6 Hypothetical Accident Conditions

As with normal conditions of transport, the applicant noted that the cask ambient conditions are the same for the SLOWPOKE fuel core as for the MTR fuel. Therefore the technical argument by the applicant is consistent in that the maximum temperature of all package body components or the SLOWPOKE contents would be bounded by the maximum package component temperatures for the MTR fuel contents. It also follows for hypothetical accident conditions that the package inner shell temperature for the MTR fuel contents bounds the maximum package inner shell temperature for the SLOWPOKE fuel core configuration. The maximum component temperatures were calculated by adding the change in temperature at steady state conditions to the maximum design basis heat loading at the inner shell during accident conditions. This resulted in a maximum temperature of 359°F and 424°F for the fuel basket and fuel cladding, respectively. The staff has reviewed the package design, construction, and preparations for shipment and concludes that the package material and component temperatures will not exceed the specified allowable short time limits during hypothetical accident conditions consistent with the tests specified in 10 CFR 71.73.

3.7 Conclusion

The NRC staff has reviewed the calculations and results of the methodology and has determined that they are representative and conservative for this application. The NRC staff has also determined that use of the higher heat loading of MTR fuel as being a surrogate for the lower heat loading of the SLOWPOKE fuel core is appropriate and acceptable.

Based on review of the statements and representations in the application, the staff concludes that the thermal analysis of the SLOWPOKE fuel core has been adequately described and evaluated and that the addition of the SLOWPOKE fuel core as approved contents meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

The revisions requested by NAC do not affect the containment system and do not alter the staff's previous containment evaluation of the NAC-LWT package. Therefore, the package remains in compliance with the containment requirements in 10 CFR Part 71. The staff did not reevaluate this area for this amendment request.

5.0 SHIELDING EVALUATION

NAC submitted an application for an amendment to the certificate of compliance for the NAC-LWT package to incorporate a SLOWPOKE spent fuel core as approved contents for transport. This revision is similar to that of the Revision No. 56 to the certificate of compliance that authorized the shipment of SLOWPOKE fuel pins in a SLOWPOKE fuel canister.

The staff reviewed the addition of the new contents using the guidance in Section 5 of NUREG-1617. The staff's evaluation of the applicant's changes to the shielding evaluation follows. This evaluation is based on the NAC SAR Revision 43 dated January 2015 and the changes described in NAC-LWT SAR Revision LWT-15A dated February 2015 as supplemented by NAC-LWT SAR Revision LWT-15C dated June 2015.

5.1 Description of the Shielding Design

5.1.1 Packaging Design Features

The staff reviewed Chapter 1, "General Information," 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 NAC-LWT is a cylindrical packaging system. The shielding design features of the NAC-LWT include multi-walled centrically shielding layers with various materials that surround the fuel. This includes stainless steel and lead for gamma shielding and a borated water/ethylene glycol mixture for neutron shielding.

5.1.2 Codes and Standards

The staff finds that the NAC-LWT SAR identifies the appropriate regulations in 10 CFR Part 71 throughout Chapter 5. The staff also verified that the NAC-LWT SAR appropriately states that the American National Standards Institute (ANSI)/American Nuclear Society (ANS) ANSI/ANS 6.1.1-1977, "Neutron and Gamma-Ray Flux to Dose Rate Factors," version for the flux to dose

rate conversion factors was used. The staff finds this acceptable because this is consistent with the acceptance criterion in accordance with the guidance in NUREG-1617.

5.1.3 Summary Table of Maximum Radiation Levels

The staff examined the summary tables for the NAC-LWT with SLOWPOKE fuel in Tables 5.3.23-7 and 5.3.23-8 of the NAC-LWT SAR. The staff reviewed these tables to ensure that the NAC-LWT meets the requirements in 10 CFR 71.47 and 10 CFR 71.51. Since the NAC-LWT SAR states that the NAC-LWT 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 175.1 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 3.1 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 hypothetical accident conditions does not exceed 1 rem/hr at 1 meter from the external surface of the package. The highest calculated dose after subjecting the package to the tests and conditions for hypothetical accident conditions is 80.7 mrem/hr, 1 meter from the package surface. The staff finds that this meets a requirement of 10 CFR 71.51(a)(2).

5.2 Source Specification

The applicant is adding one SLOWPOKE fuel core with undamaged fuel rods loaded into a SLOWPOKE basket. This will be accompanied by empty intermediate MTR-42 baskets and a bottom MTR-42 basket so that the SLOWPOKE basket and its contents is adjacent to the NAC-LWT package lid, as shown in NAC Drawing No. LWT 315-40-185. The SLOWPOKE basket has a spacer bolted to the lid so that the fuel will be located at the bottom of the SLOWPOKE basket, as shown in NAC Drawing No. LWT 315-40-186.

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 1.2-17 of the NAC-LWT SAR. Table 5.1.1-2 of the NAC-LWT SAR gives the characteristics used in the shielding analysis. The staff verified that these parameters are consistent with those listed in Table 1.2-17 of the NAC-LWT SAR.

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. Only the radial reflector was modeled to obtain the source term due to limitations of the TRITON code in the 2-D evaluation.

As the exact configuration of the rods in the core is unknown, the applicant modeled two core configurations, a reference and a compact. These are shown in Figures 5.3.23-2 and 5.3.23-3 of the NAC-LWT SAR, respectively. The reference core configuration produced the maximum gamma source spectra and therefore it was used in the dose rate evaluation. The maximum

source was located in the inner ring and this source term was applied to all the fuel rods in the core when performing the shielding analyses. The staff finds this acceptable.

The applicant listed SLOWPOKE core information in Table 5.2.23-1 of the SAR and the values used in the TRITON modeling to obtain the source term in Table 5.2.23-2. The applicant changed the parameters to create a more conservative source term than the actual source term by reducing enrichment, increasing fuel mass and irradiation time. The staff verified these changes and finds them conservative and acceptable.

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 flux distribution 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 irregular lattice configurations and non-lattice configurations.

The NRC has supported development of the TRITON code for licensing. It is widely used and benchmarked for light-water reactor spent fuel depletion. Although TRITON has not been benchmarked for SLOWPOKE fuel depletion analyses, the staff finds that is acceptable for use in this application, given the use of conservative analytical assumptions and the margin to the regulatory dose rate limits. In addition, SLOWPOKE type reactors are used to generate pulse neutron source for radiation or other research purposes. The reactor typically runs at power with a very short duration. Therefore, assuming continuous depletion in source term calculation significantly overestimates the source because the decay time during the downtime is not included. Therefore, overestimate of the source can compensate for any uncertainties of the code for depletion analysis of this type of fuel and reactor. The staff does not find that the uncertainty associated with the TRITON code 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.

According to the reference TRITON input file provided in Figure 5.3.23-4 of the NAC-LWT SAR, 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.

5.2.1 Gamma Source

The applicant calculated the gamma source of the spent SLOWPOKE fuel based on the fuel burnup and cooling time using the TRITON code. The applicant specified the gamma source term as a function of energy for the SLOWPOKE fuel per rod in Table 5.3.23-4 of the application.

All of the structural materials are made of aluminum (as stated in Calculation Package No. 50026-2001, page 51, Section 7.1.2) whose activated isotopes have a short half-life (on the order of seconds) and would not contribute to external dose rate given the required cooling times for this content.

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 applicant also calculated the neutron source of the spent SLOWPOKE fuel based on the fuel burnup and cooling time using the TRITON code. The applicant specified the neutron source as a function of energy for the SLOWPOKE fuel per rod. This is listed in Table 5.3.23-3 of the application.

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 shielding calculations and the staff found that it provides sufficient 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 adjusting the neutron source using the subcritical neutron $S^* = S/(1-k_{eff})$ population equation.

5.3 Model Specification

The staff reviewed Chapter 2, "Structural Evaluation," and Chapter 3 "Thermal Evaluation," of the application to determine the effects of the normal conditions of transport and hypothetical accident conditions on the packaging and its contents. Section 5.3.23.2 of the application discusses the evaluation of the NAC-LWT with the SLOWPOKE core model for normal conditions of transport and hypothetical accident conditions tests and conditions. Under both conditions, the fuel rods are explicitly modeled in the same reference configuration that produced the bounding source spectra. Section 4.2 of NUREG/CR-6802, states that the modeling of a full pin-by-pin geometry is generally equivalent to a smeared assembly model, therefore the staff finds that differences in the pin configurations would be negligible in the shielding calculation. Therefore staff finds this acceptable.

For both normal conditions of transport and hypothetical accident conditions the fuel is modeled in its as-loaded position near the top of the cavity. Although the presence of the spacers are credited for maintaining the position of the SLOWPOKE fuel core, any material within the spacers is neglected and does not provide any radiation attenuation as part of the shielding model.

The applicant includes the radial neutron shield and shield shell and the impact limiters with reduced dimensions.

Chapter 2 of the NAC-LWT SAR shows that normal conditions of transport tests required by 10 CFR 71.71 do not impact the geometry of the package. However the impact limiters experience some crush and deformation. The applicant includes the impact limiters in the normal conditions of transport shielding model. The applicant truncates the radial dimension of the impact limiter to account for the deformation. The applicant did not discuss the modeling of the impact limiter in the axial direction, based upon the thickness of the shielding components in the axial direction, and the presence of the axial spacer within the SLOWPOKE core basket, the staff has reasonable assurance that this package would be limited by the radial dose rate and finds that additional detail with respect to the deformation of the impact limiter in the axial direction is not necessary. The staff verified the amount of displacement shown in Table 2.6.7-32 of the SAR and found that the effects of the normal conditions of transport 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 hypothetical accident conditions 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; nor does the applicant take credit for the space in which these components would occupy. The applicant models radial and axial lead slump simultaneously, which is conservative as they would not realistically experience slump simultaneously. The amount of lead slump applied in the axial direction is conservative with respect to the evaluation of lead slump in Chapter 2 of the SAR. Section 2.6.11 of the SAR documents fabrication procedures of the radial lead shield and indicates that heaters are applied to the cask shells during lead pour to assure no significant radial void exists in the cask under normal conditions. The values being applied in void calculations of Chapter 2 and Section 5.3.23 of the SAR conservatively assume that a lead gap exists. The staff finds that the applicant has considered the effects of lead slump and finds this acceptable.

5.3.1 Configuration of Source and Shielding

The staff examined the dimensions of the SLOWPOKE core basket used in the shielding model as described by Table 5.3.23-6 of the application. The staff verified that the dimensions were consistent with the basket drawings presented in Section 1.4 of the NAC-LWT SAR. The staff examined the sample MCNP input file for normal conditions of transport and hypothetical accident conditions in Figures 5.3.23-7 and 5.3.23-11 and verified that the dimensions of the model were consistent with the package drawings presented in Section 1.4 of the SAR. The applicant used nominal dimensions for modeling the package. The staff finds this acceptable based on the margin to regulatory limits in the calculated dose rates as well as conservative assumptions applied within the analysis. The staff does not find the potential dose rate increase due to manufacturing tolerances would be enough to cause the package to exceed regulatory limits.

The applicant did not consider axial profile effects on the source profile. They state that there is no axial burnup profile available in open literature. The applicant states that the beryllium axial reflectors will serve to flatten the axial burnup profile. The staff finds this is the typical operation of a SLOWPOKE type neutron source reactor and the fuel length is very short compared with commercial reactors. Therefore, the fuel burnup profile will not exhibit a large peaking in the middle section of the fuel. As such, the staff finds not considering the axial profile acceptable given the relatively small size of the core and other conservative assumptions in the model as well as margins to regulatory dose rate limits.

The applicant did not consider effects of damaged fuel, therefore all the fuel rods in the SLOWPOKE core must be undamaged.

Although the application states that the NAC-LWT is to be shipped by exclusive use, dose rates meet regulations for non-exclusive use. From the information in Figure 5.2.23-7 of the NAC-LWT SAR the staff determined that the applicant assumed that the transport vehicle extended an additional 72 cm (a little over 2 feet) from beyond the edge of the package surface. The staff found this to be a reasonable assumption.

The staff verified that the dose rate locations include all locations prescribed by 10 CFR 71.47(b) and 71.51(a)(2). This includes the package surface and 2 meters from the package surface, 2 meters from the transportation vehicle edge and the cab of the transportation vehicle (any normally occupied space). The applicant did not include an evaluation at the transportation vehicle surface because this dose rate is met at the package surface; therefore it will also be met at the vehicle surface. The dose rates at these locations are summarized in Table 5.3.23-7 of the application. The highest dose rate is at the side of the package near the top. The values reported in Table 5.3.23-7 agree with those in Figures 5.3.23-12 through 5.3.23-15. The dose rates include contributions from gamma, neutron and n-gamma reactions. The highest contribution comes from the gamma dose.

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 and bottom of the cask. The staff found that the applicant has addressed streaming effects.

5.3.2 Material Properties

The NAC-LWT is made of stainless steel, lead, and a neutron shield jacket containing a borated water/ethylene glycol mixture for neutron shielding. The staff verified that the applicant identified the materials and mass densities of the canister, basket, package, and impact limiter. These are specified in Table 5.3.23-5 of the application. 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 applicant assumes that the impact limiters are made of aluminum with a density of 0.5 g/cm^3. The impact limiters are made into a "honeycomb" structure. Based on the dimensions of the impact limiters from the license drawings in Section 1.4 and the weight of the impact limiters in Table 2.2.1-1 of the SAR, the staff verified that the effective density of this component used by the applicant in the shielding model is acceptable. 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 does not assume the neutron tank is present for hypothetical accident conditions. Therefore the staff found that the applicant has appropriately addressed the effect temperature has on the neutron shielding material.

5.4 Evaluation

5.4.1 Methods

For the shielding analysis the applicant uses the MCNP5 code, Version 1.6. From the information in Figures 5.2.23-7 and 5.2.23-11 of the SAR, the applicant used the default cross sections provided with this version of the MCNP code. 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 a representative 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 NAC-LWT SAR states that the shielding evaluation uses the ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors in all the package 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 viewed the calculated radiation levels as displayed in Figures 5.3.23-12 through 5.3.23-15 of the application. The staff confirmed that the calculated radiation levels under both normal conditions of transport and hypothetical accident conditions for undamaged fuel are in agreement with Table 5.3.23-7 of the applications and that they satisfy the limits in 10 CFR 71.47(b) 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 normal conditions of transport and hypothetical accident conditions.

5.5 Evaluation Findings

Based on the staff's evaluation above of the NAC-LWT, the staff has the following evaluation findings for the addition of SLOWPOKE core:

- 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 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 Section 5.3 of this SER, the staff found that the radiation levels will not significantly increase during normal conditions of transport consistent with the tests specified in 10 CFR 71.71.

- As documented in Section 5.3 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 after hypothetical accident conditions, consistent with the tests specified in 10 CFR 71.73.

6.0 CRITICALITY EVALUATION

The staff reviewed the application to revise the NAC-LWT package to verify that the package criticality safety design has been described and evaluated under normal conditions of transport and hypothetical accident conditions 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.

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

6.1 Description of Criticality Design

Staff reviewed both the general information chapter in the NAC-LWT SAR and the information presented in the criticality safety chapter. This amendment allows for one SLOWPOKE fuel core containing up to 298 undamaged SLOWPOKE fuel rods contained in a SLOWPOKE basket to be transported in a NAC-LWT package.

6.2 Fissile Material Contents

Materials of the core are undamaged SLOWPOKE fuel rods and contain highly enriched uranium in an aluminum matrix material. Uranium enrichment may be up to 95.3 wt.% ^{235}U.

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configuration

The configuration proposed for the NAC-LWT would allow one undamaged SLOWPOKE core consisting of 298 undamaged SLOWPOKE fuel rods contained in a SLOWPOKE fuel basket.

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 6.7.5-2 of the SAR.

6.3.3 Computer Codes and Cross Section Libraries

The applicant used the MCNP5 code package with the ENDF/B-VI cross-section set to develop a model to evaluate this SLOWPOKE contents in the NAC-LWT cask.

6.3.4 Demonstration of Maximum Reactivity

For the criticality evaluation of both normal conditions of transport and hypothetical accident 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 package contents. 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 core in its basket in the NAC-LWT package were with the fuel rod's pitch reduced in a flooded condition.

6.4 Single Package Evaluation

The fuel is modeled as an intact core containing 298 fuel rods in a hexagonal pitch configuration. The applicant explicitly modeled the fuel rods, basket, cask cavity, and radial shields. The basket includes a stainless steel lid with spacers and is conservatively modeled as 3.5 inches thick. The model includes the 11.25 inches of steel within the NAC-LWT lid for neutron reflection. The axial geometry of the basket containing the SLOWPOKE fuel core is modeled for all parametric studies. The applicant took credit for the spacing of the MTR-42 baskets and ignored the stainless steel material which is conservative since it is a neutron absorber.

6.5 Evaluation of Package Arrays under Normal Conditions of Transport

For the normal conditions of transport, 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. Based on these bounding conditions, the maximum k_{eff} +2σ calculated by the applicant was 0.8711.

6.6 Evaluation of Package Arrays under Hypothetical Accident Conditions

Similar to the evaluation for normal conditions of transport, the NAC-LWT cask under hypothetical accident conditions used the bounding conditions identified above, including the removal of the neutron shielding as 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 0.8720.

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 (95.3 wt.% for SLOWPOKE core vs. 93.2 wt.% in the critical set), the maximum reactivity energy of the average neutron lethargy causing fission of 0.08 eV is within the area of applicability, and the applied upper subcritical limit of 0.9171 based on the energy of the average neutron lethargy causing fission, bounds the use of this fuel.

6.8 Benchmark Evaluation

Burnup credit is not used in the evaluation of the SLOWPOKE core in this package and fuel is assumed to be fresh.

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 core 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 core 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 normal conditions of transport and hypothetical accident conditions.
- Staff found that the benchmark evaluation of the calculations were appropriate for the evaluation of a SLOWPOKE core as contents in the NAC-LWT package.
- Staff found that burnup credit was not used in the evaluation of the SLOWPOKE core 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 NAC-LWT loaded with a SLOWPOKE core in a SLOWPOKE basket. Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's criticality analyses demonstrate that the package design continues to meet the criticality safety requirements in 10 CFR Part 71.

7.0 OPERATING PROCEDURES EVALUATION

The staff reviewed Chapter 7 of the application 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 7.1.18 of the application was added to include the procedures for loading of the SLOWPOKE core. Sections 7.2.3 and 7.2.4 already include procedures for wet and dry unloading the SLOWPOKE fuel, respectively.

The staff reviewed and evaluated the proposed loading procedures of the SLOWPOKE core. Based on the statements and representations in the application, the staff concluded 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 certificate 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 SAR, as amended.

8.0 ACCEPTANCE TESTS AND MAINTENANCE REVIEW

The revisions requested by NAC do not affect the acceptance tests and maintenance programs and do not alter the staff's previous evaluation of the acceptance tests and maintenance programs of the NAC-LWT package. Therefore, the package remains in compliance with the acceptance tests and maintenance program requirements in 10 CFR Part 71. The staff did not reevaluate this area for this revision request.

CONDITIONS

The following changes have been made to the certificate:

The package name was changes from LWT to NAC-LWT in Condition 5.(a)(2).

Condition 5.(a)(3)(iii) was revised to include the following drawings:

LWT 315-40-185, Rev. 0	LWT Transport Cask Assembly, SLOWPOKE Contents
LWT 315-40-186, Rev. 2	Fuel Core Basket Assembly, SLOWPOKE
LWT 315-40-187, Rev. 1	Basket Lid Assembly, SLOWPOKE

Conditions 5.(b)(1)(xxi) was added to specify the type and form of the SLOWPOKE core contents.

Condition 5.(b)(2)(xxii) was added to specify the quantity of material per package, and specify conditions of transport for the contents.

Condition 5.(c) was revised to add a CSI of 100 for transport of the SLOWPOKE core contents.

Condition 20 was revised to authorize continued use of Revision 64 of the certificate for approximately 2 years to support completion of the high enrich uranyl nitrate liquid shipments.

The references section has been updated to include the application dated February 25, 2015, as supplemented on June 5, 17, and 19, 2015,

CONCLUSION

CoC No. 9225 has been revised to add a SLOWPOKE core as authorized contents, as specified above, in the Model No. NAC-LWT package. Based on the statements and representations in the application, as supplemented, and with the conditions listed above, the staff agrees that with these changes, the package continues to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9225,
Revision No. 65 on July 23, 2015