U.S. Department
of Transportation

**Pipeline and
Hazardous Materials
Safety Administration**

East Building, PHH-23
1200 New Jersey Avenue Southeast
Washington, D.C. 20590

# COMPETENT AUTHORITY CERTIFICATION FOR A TYPE B(U)F FISSILE RADIOACTIVE MATERIALS PACKAGE DESIGN CERTIFICATE USA/9225/B(U)F-96, REVISION 48

This certifies that the radioactive material package design described has been certified by the Competent Authority of the United States as meeting the regulatory requirements for a Type B(U)F packaging for fissile radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2].

1. Package Identification - NAC-LWT.

2. Package Description and Authorized Radioactive Contents - as described in U.S. Nuclear Regulatory Commission Certificate of Compliance No. 9225, Revision 55 (attached).

3. Criticality - The minimum criticality safety index is as assigned in NRC Certificate of Compliance. The maximum number of packages per conveyance is determined in accordance with Table X of the IAEA regulations cited in this certificate.

4. General Conditions -

   a. Each user of this certificate must have in his possession a copy of this certificate and all documents necessary to properly prepare the package for transportation. The user shall prepare the package for shipment in accordance with the documentation and applicable regulations.

   b. Each user of this certificate, other than the original petitioner, shall register his identity in writing to the Office of Hazardous Materials Technology, (PHH-23), Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington D.C. 20590-0001.

   c. This certificate does not relieve any consignor or carrier from compliance with any requirement of the Government of any country through or into which the package is to be transported.

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[1] "Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised)," published by the International Atomic Energy Agency(IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

**CERTIFICATE USA/9225/B(U)F-96, REVISION 48**

d. This certificate provides no relief from the limitations for transportation of plutonium by air in the United States as cited in the regulations of the U.S. Nuclear Regulatory Commission 10 CFR 71.88.

e. Records of Quality Assurance activities required by Paragraph 310 of the IAEA regulations[1] shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the applicable requirements of Subpart H of 10 CFR 71.

5. Special Conditions -

a. Air transport is not authorized.

b. The only contents authorized by this revision are as listed in the January 10, 2012 letter from the Nuclear Regulatory Commission to NAC (attached) for a one-time shipment of five special fuel assemblies, loaded in the MTR basket with the center basket opening blocked to prevent misloading.

c. USA/9225/B(U)F-96, Revision 47, is the only certificate authorized for continued use under the "previous revisions" clause found in paragraph 7.

6. Marking and Labeling - The package shall bear the marking USA/9225/B(U)F-96 in addition to other required markings and labeling.

7. Expiration Date - This certificate expires on December 31, 2013. On December 31, 2013, this certificate supersedes all previous revisions of USA/9225/B(U)F-96.

**CERTIFICATE USA/9225/B(U)F-96, REVISION 48**

This certificate is issued in accordance with paragraph 814 of the IAEA Regulations and Section 173.471 and 173.472 of Title 49 of the Code of Federal Regulations, in response to the January 26, 2012 petition by NAC International, Norcross, GA, and in consideration of other information on file in this Office.

Certified By:

Feb 17 2012
(DATE)

Dr. Magdy El-Sibaie
Associate Administrator for Hazardous Materials Safety

Revision 48 - Issued to endorse U.S. Nuclear Regulatory Commission Certificate of Compliance No. 9225, Revision 55, as amended by NRC letter dated January 10, 2012 to authorize a one-time shipment of five special fuel assemblies.

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

January 10, 2012

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

SUBJECT: AUTHORIZATION FOR A ONE-TIME SHIPMENT OF THE DOUNREAY FUEL CONTENTS IN THE MODEL NO. NAC-LWT PACKAGE (TAC NO. L24602)

Dear Mr. Patko:

As requested by your application dated November 10, 2011, pursuant to Title 10 of the Code of Federal Regulations Part 71, Certificate of Compliance (CoC) No. 9225, for Model No. NAC-LWT package, is amended with the following condition:

A one-time shipment of five (5) special fuel assemblies in the currently certified Model No. NAC-LWT transportation package specified as follows:

- Three (3) 4x4 square EK-10 rod arrays (two with 16 rods; one with 15 rods)
    - $UO_2$-Mg fuel matrix/Al clad
    - Nominal 10 wt.% U-235
    - < 120 g U-235 per array
    - The maximum amount Uranium per assembly analyzed is 1400g
    - The maximum burnup analyzed is 20,000 MWd/MTU
    - The minimum cooling time is 28.3 years
- One (1) concentric tube ITR assembly (four square tubes)
    - U/Al alloy fuel/Al clad
    - Similar to DIDO assembly currently authorized, but uses four square "boxes" instead of cylindrical tubes
    - Nominal 90 wt.% U-235
    - < 170 g U-235 per assembly
    - The maximum Uranium per assembly analyzed is 220 g
    - The maximum burnup analyzed is 15,000 MWd/MTU
    - The minimum cooling time is 10 years
- One (1) hexagonal array (91 rods) TTR assembly
    - U/Al alloy fuel/Al clad
    - Nominal 90 wt.% U-235
    - < 400 g U-235 per assembly

- o The maximum Uranium per assembly analyzed is 500g
- o The maximum burnup analyzed is 60,000 MWd/MTU
- o The minimum cooling time is 22.6 years

The assemblies will be transported in the currently certified Metal Test Reactor (MTR) basket with the center basket opening blocked to prevent misloading.

The following additional conditions apply:

- All other conditions of CoC No. 9225 shall remain the same.
- This authorization shall expire on December 31, 2013.

If you have any questions regarding this authorization, please contact me or Kim Hardin of my staff at (301) 492-3339.

Sincerely,

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

Docket No. 71-9225

Enclosure: Safety Evaluation Report

cc: R. Boyle, Department of Transportation
J. Shuler, Department of Energy

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

## SUMMARY


By application dated November 10, 2011, NAC International (NAC or the applicant) requested an authorization to Certificate of Compliance (CoC) No. 9225 for the Model No. NAC-LWT transportation package. NAC requested a one-time authorization to ship special fuel assemblies.

This shipment is necessary to support a shipment from the Dounreay Nuclear Facility in Scotland 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. A two-year authorization period for this one-time shipment is granted based on the fact that NNSA may not make the 2012 shipment plans, which would move the shipment date to a 2013 shipment date. This shipment is in the interest of U.S. national security.

CoC No. 9225 has been amended by letter based on the statements and representations in the application, and 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

By application dated November 10, 2011, NAC requested a one-time authorization to ship the following five special fuel assemblies in up to six cells in the currently certified Model No. NAC-LWT transportation package specified as follows:

- Three (3) 4x4 square EK-10 rod arrays (two with 16 rods; one with 15 rods)
    - $UO_2$-Mg fuel matrix/Al clad
    - Nominal 10 wt.% U-235
    - < 120 g U-235 per array
    - The maximum amount Uranium per assembly analyzed is 1,400g
    - The maximum burnup analyzed is 20,000 MWd/MTU
    - The minimum cooling time is 28.3 years

- One (1) concentric tube ITR assembly (four square tubes)
    - U/Al alloy fuel/Al clad
    - Similar to DIDO assembly currently authorized, but uses four square "boxes" instead of cylindrical tubes

- Nominal 90 wt.% U-235
- < 170 g U-235 per assembly
- The maximum Uranium per assembly analyzed is 220 g
- The maximum burnup analyzed is 15,000 MWd/MTU
- The minimum cooling time is 10 years

- One (1) hexagonal array (91 rods) TTR assembly

  - U/Al alloy fuel/Al clad
  - Nominal 90 wt.% U-235
  - < 400 g U-235 per assembly
  - The maximum Uranium per assembly analyzed is 500g
  - The maximum burnup analyzed is 60,000 MWd/MTU
  - The minimum cooling time is 22.6 years

The assemblies will be transported in the currently certified Metal Test Reactor (MTR) basket with the center basket opening blocked to prevent misloading.

**2.0 Structural Review**

As summarized in Attachment one to the request, NAC also performed an evaluation of the structural integrity of the Dounreay fuel for the NCT and HAC of the transport. The evaluation includes side and end drops of the fuel in the package using the design basis decelerations for the Model No. NAC-LWT. The heaviest assembly weighs less than 11 pounds, which is bounded by the currently certified 80 pound per cell content weight limit.

Based on the evaluation summary, the staff has reasonable assurance that the package will continue to meet the structural requirements of 10 CFR Part 71.

**3.0 Thermal Review**

The total heat load for the contents is calculated to be less than 3 watts (1998 data).

Based on the statements and representations in the application, there are no changes that affect the currently approved thermal evaluation of the payload during the shipment and there continues to be reasonable assurance that the package will meet the thermal requirements of 10 CFR Part 71.

**4.0 Containment Review**

The package is approved as leaktight, which does not change with this approval.

Based on the statements and representations in the application, as supplemented, there are no changes that affect the currently approved containment evaluation of the payload during the shipment, and there continues to be reasonable assurance that the package will meet the containment requirements of 10 CFR Part 71.

**5.0 Shielding Review**

This section presents the findings of the shielding review for a request for authorization to approve shipment of the Dounreay fuel material under the CoC No. 71-9225 for the Model No. NAC-LWT transportation package. The staff reviewed the source term calculation analysis of the package presented in the calculation package, in which the applicant provided an updated source terms analysis for the licensing of EK-10, IRT-2M, and TTR fuel in the Model No. NAC-LWT.

## 5.1 Description of the Shielding Design

### 5.1.1 Packaging Design Features

The shielding design for this authorization is based on source term calculations. The source term calculations are performed for five special fuel assemblies to be transported in the Model No. NAC-LWT package using the currently approved MTR fuel basket. The Model No. NAC-LWT is an approved package that allows transport of seven 30-watt element (554,700 MWd/MTU / 1,200 days cooled) assemblies in the MTR basket. The five special fuel assemblies consist of three different types of fuel assemblies, EK-10 (3 assemblies), IRT-2M (1 assembly), and TTR (1 assembly). Detailed descriptions of these assemblies are shown in Table 6-1 of the Calculation Package.

### 5.1.2 Codes and Standards

The codes and standards applied to this amendment are the same as established in the currently certified MTR basket.

### 5.1.3 Summary Table of Maximum Radiation Levels

The information on the special fuel assemblies was provided by the applicant and the staff used them to compare with the design basis shielding source terms for the Model No. NAC-LWT package in the MTR fuel configuration. Dose rate calculations were not provided by the applicant due to the source term comparison. Comparison between the five special fuel assemblies and the MTR design basis fuel assemblies demonstrate that the gamma source strength for the five special fuels assemblies is two orders of magnitude lower than the design basis (MTR) for gammas and three or more orders of magnitude below that for neutrons.

## 5.2 Source Specifications

### 5.2.1 Gamma Source

Gamma source strength for the five special fuel assemblies is shown in Table 1-1 of the Calculation Package. For the five special fuel assemblies, the total gamma source term is $1.47\times10^{13}$ gamma/sec and $5.55\times10^{12}$ MeV/sec. The design basis gamma source term is $1.25\times10^{15}$ gamma/sec and $5.38\times10^{14}$ MeV/sec. Comparing these gamma source terms, the five special fuel assemblies are lower in magnitude in comparison with the design basis (MTR fuel assemblies).

### 5.2.2 Neutron Source

The neutron source strength for the five special fuel assemblies is shown in Table 1-2 of the Calculation Package. For the five special fuel assemblies, the total neutron source term is $2.51\times10^{3}$ neutron/sec. The design basis neutron source term is $6.47\times10^{6}$ neutron/sec. Comparing these neutron source terms, the five special fuel assemblies are lower in magnitude in comparison with the design basis (MTR fuel assemblies).

Table 1-3 shows the fission product gases and some of the particulate isotopes. In terms of activity, there is a significant difference between the five special fuel assemblies and the MTR design basis. For example, for Cs-137, the amount of activity is 232 Ci for the five special fuel assemblies, while this is 50,000 Ci for the design basis.

## 5.3 Model Specification

### 5.3.1 Configuration of Source and Shielding

The five special fuel assemblies are loaded into the MTR basket. These fuel assemblies include three EK-10 assembly, one ITR-2M assembly, and one TTR fuel assembly. A total of five MTR baskets are permitted for transport, while only one basket of the special fuel assemblies is going to be used in the Model No. NAC-LWT.

### 5.3.2 Material Properties

The special fuel design basis input is shown in Table 4.1 of the Calculation Package. This information was provided by DOE.

For the EK-10 fuel assembly, the Uranium per assembly is 1288 g, maximum burnup is 14,800 MWD/MTU, and the cooling time is 10,349 days.

For the IRT-2M fuel assembly, the Uranium per assembly is 189.8 g, maximum burnup is 9,180 MWD/MTU, and the cooling time of 3,653 days.

For the TTR fuel assembly, the Uranium per assembly is 455 g, maximum burnup is 48,600 MWD/MTU, and the cooling time of 8,281 days.

## 5.4 Evaluation

The applicant performed source term analyses for the five fuel assemblies to be transported in the Model No. NAC-LWT package using the MTR fuel basket. The fuel assemblies mentioned above are going to be loaded into the MTR basket.

The method of analysis used by the applicant included a review of previously performed analyses and updating of fuel source term models where necessary. Also, some evaluations of the payloads were performed using various updated code and cross section sets. Comparison between the special fuel and the MTR design payloads in the evaluation were identified in the Calculation Package.

The applicant stated that all previous results were generated using SCALE 4.3 SAS2H with the 27-group ENDF/B-IV cross section library. The applicant stated that this code/library set has been superseded by both updated code version and cross section libraries. Table 6-7 shows a summary of code/library comparison, which includes SAS2H, T-DEPL from SCALE 4.3, SCALE 5.1, and SCALE 6. The code/libraries used in the evaluations were 27-group (SCALE 4.3), 44-group (SCALE4.3), 238-group (SCALE 4.3), 44-group (SCALE 5.1), 238-group (SCALE 5.1), 44-group (SCALE 6), and 238-group (ENDF/VII) (SCALE 6).

The data for the special fuel design basis was presented in Table 4-1 of the calculation package. The applicant provided SAS2H input files for all the analyses. For this authorization, revisions of the SAS2H model involved changing dimension and depletion parameters to account for the updated and bounding data. To provide a bounding fuel assembly description, the applicant modified each fuel type by increasing the uranium mass and decreasing the weight percent of U-235 in Uranium. Burnup was increased, and the cooling time was decreased to increase the source term. On Page 18 of 37 of the Calculation Package, the applicant provided a table describing the design basis fuel.

The staff reviewed the applicant's source term calculations used in the analyses. Also, the staff checked the code input in the calculation packages and confirmed that the proper material properties and boundary conditions were used. The staff performed source term calculations using SCALE 6 to compare photon and neutron sources. The staff concludes that the source term calculations for the special fuel are a small fraction of the design basis source terms and will not exceed the regulatory limits.

### 5.5 Conclusions

The staff evaluated the shielding safety analysis for the packages that are loaded with the five special fuel assemblies. The staff found that the applicant has correctly modeled and analyzed the shielding safety of these packages. 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 71.47 and 10 CFR Part 71.51(a)(2).

## 6.0 Criticality Evaluation

NAC submitted a request for authorization for shipment of the Dounreay fuel material under NRC regulations in 10 CFR Part 71 in the Model No. NAC-LWT transportation package. 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) allows shipment of Light Water Reactor (LWR) and research reactor fuel. This authorization will allow a one-time shipment of five special fuel assemblies in the MTR fuel basket. NAC performed a criticality evaluation of the shipment and submitted it with the request (Reference 1). The staff reviewed this calculation as well as the pertinent information from the NAC-LWT Safety Analysis Report (SAR) (Reference 2).

### 6.1 Description of Criticality Design

The applicant controls criticality by limiting the amount of fissile material that will be contained within the package. The neutron multiplication factor (k-effective, or k-eff) will be less than 0.95 during all Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC).

The applicant stated in Reference 3 that this is a single shipment using a single package. The staff finds that by specifying the allowable number of packages that may be transported in a single shipment, that the applicant meets the requirements of 10 CFR 71.35(b).

The staff found that the description of the packaging was described in sufficient detail to provide an adequate basis for its evaluation and that the description included types and dimensions of materials of construction. The staff found that the applicant met the requirements of 10 CFR 71.31(a)(1) and 10 CFR 71.33(a)(5). The staff examined the sketches of the model used for the criticality calculations and verified that the dimensions and materials were consistent with those in the drawings of the actual package.

The staff verified that the applicant provided sufficient information for all materials used in the models of the packaging and contents. There are no materials in the package that need to be adjusted to be consistent with accident conditions, i.e. there are no materials used in the model that change form, such as a neutron shield or neutron absorbers that could melt, as assumed in the calculations needed to maintain sub-criticality. The applicant did not take credit for any kind of neutron absorber material. The applicant did not request credit for burnable poisons in the fuel.

The applicant provided a summary table of the criticality evaluations in Table 1-1 in Reference 1 of the application. The staff verified that the table included the maximum value of k-eff. For the limiting conditions for the Model No. NAC-LWT with the Dounreay fuel, the applicant's analysis gave a maximum k-eff of 0.58. It was not clear to the staff if these values included the code standard deviation or bias. However, in Reference 2 the applicant showed that typical code bias for NAC validations are less than 2% Δk-eff for applications involving Low Enriched Uranium (LEU), High Enriched Uranium (HEU), fast fission, and Mixed Oxide (MOX) materials. Considering the low value of k-eff, the staff found that the summary table showed that the package meets the sub-criticality criterion.

### 6.2 Fissile Material Contents

The applicant provided the physical characteristics of the five special assemblies. There will be three EK-10 assemblies, one IRT-2M assembly, and one TTR assembly. The EK-10 has a square rod array with 15 or 16 rods. It has a $UO_2$-Mg fuel matrix with Al cladding. It is 10% enriched with less than 120g U-235 per assembly. The IRT-2M is a concentric tube assembly with four square tubes. It is U-Al fuel with Al cladding and it is 90% enriched with less than 170g U-235. The TTR fuel is also U-Al with Al cladding. It is a hexagonal array of 91 rods with less than 400g U-235. Bounding fuel specifications were in Table 6-1 of Reference 1.

The applicant referenced some calculations from the NAC-LWT SAR (Reference 2) for showing the possible effect of geometric tolerance and mechanical perturbations. The staff found that any increase in reactivity due to these factors would be small in comparison to the safety margin in the low k-eff value.

The staff found that the applicant described the contents in sufficient detail to provide an adequate basis for this evaluation. The staff found that the applicant adequately defined the type, maximum quantity, and chemical and physical form of the fissile material. The staff found that this application met the requirements of 10 CFR 71.31(a)(1), 10 CFR 71.33(b)(1), 10 CFR 71.33(b)(2) and 10 CFR 71.33(b)(3).

### 6.3 General Considerations for Criticality Evaluations

The applicant performed criticality evaluations for an infinite array (i.e., used infinite reflective boundary conditions) of packages in the damaged and undamaged condition, optimally moderated with water, and in the most reactive form of the fissile material. The applicant did not assume close reflection[1] of the containment system on all sides. The applicant found that voiding the exterior increases the reactivity because it allows more neutron interaction between the packages. The staff found this assumption acceptable. The applicant performed analyses to determine the optimum internal moderation. The applicant showed in Section 6.4 of Reference 1 that the most reactive configuration was with 100% water density for internal moderation. The staff found that the applicant met the requirements of 10 CFR 71.55(b).

The applicant did not perform a calculation for a single package; however, the applicant showed a large margin to criticality in their calculations. Therefore, the staff found that the reflective boundary condition would be representative enough of the single evaluation. If there were any

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[1] "Close reflection by water" is defined in 10 CFR 71.4 as immediate contact by water of sufficient thickness for maximum reflection of neutrons.

differences, it would be bounded by the conservatism in the calculation assumptions and results.

In Section 5 of Reference 1, the applicant calculated the Criticality Safety Index (CSI) to have a value of 0. This was based on the analysis performed that used a value of N equal to infinity (i.e., an infinite array of packages). The staff found that the CSI was appropriately determined per 10 CFR 71.59(b). The staff determined that the applicant met the requirements of 10 CFR 71.59(a)(3) because the value of N is not less than 0.5. The staff concluded that the applicant met the requirements of 10 CFR 71.59(a)(1) by demonstrating that an array of at least 5N packages (infinite array in this case) with nothing between the packages is subcritical.

The applicant did not provide a calculation for HAC; however, in Reference 3 the applicant stated that the fuel remains intact during NCT and HAC. The staff performed scoping calculations with MCNP5 using the maximum amount of fissile material allowed within the shipment and determined that it would be nearly impossible for the fuel to reconfigure to a critical configuration under any credible circumstances. The staff found that it would require the U-235 to reconfigure to an optimally moderated homogenous sphere of U-235 and water (at least 95% water by mass). The staff concluded that this gave reasonable assurance that the shipment will be subcritical under all NCT and HAC. The staff determined that this met the requirements in 10 CFR 71.55(e), which requires that a package and its contents be subcritical under HAC. The staff concluded that the applicant met the requirements of 10 CFR 71.59(a)(2) by demonstrating that an array of at least 2N packages under HAC is subcritical.

Since k-eff is less than 0.95 under the tests specified in 10 CFR 71.71 for NCT, the staff verified that this met the requirements of 10 CFR 71.55(d)(1), which requires that the contents be subcritical. The staff verified that the geometric form of the package contents would not be altered in such a way to affect criticality. The staff found that the applicant met the intent of 10 CFR 71.55(d)(2). The staff verified that there was no reduction in the effectiveness of the packaging for criticality prevention under NCT. Therefore, the staff found that the applicant met the requirements in 10 CFR 71.55(d)(4).

The staff did not verify that there would be no leakage of water into the containment system per 10 CFR 71.55(d)(3) because the applicant assumed full in-leakage of water at its most reactive extent for NCT and HAC. The staff found that the applicant met the requirements of 10 CFR 71.55(d)(3).

### 6.4 Benchmark Evaluation

The applicant performed the criticality evaluation using SCALE 4.3 CSAS25 using KENO-Va with the 27-group ENDF/B-IV cross section library. This code and cross section set were validated by the applicant for high enriched research reactor fuel in Section 6.5.2 of Reference 2. Since this code and cross section set have since been superseded with newer versions, the applicant performed calculations using SCALE 6 with ENDF/B-V cross sections and MCNP with ENDF/B-VI cross sections, and the results from these codes also show a large safety margin. The staff notes that it is difficult to perform validation calculations for $UO_2$-Mg fuel given the lack of available benchmarking experiments for this fuel material. However, given the large safety margin shown in the applicant's calculations, the staff determined that their current benchmarking is adequate for this calculation and that any increase in calculation uncertainty for $UO_2$-Mg could not cause the shipment to exceed any regulatory limits.

### 6.5 References

1. Calculation 65008000-6001, “Updated Criticality Analysis for the Licensing of EK-10, IRT-2M, and TTR Fuel in the NAC-LWT,” November 10, 2011 (ADAMS Accession No. ML11333A051)

2. Safety Analysis Report (SAR) for the NAC Legal Weight Truck Cask, Revision 41, NAC International, April 2010 (ADAMS Accession No. ML101750226)

3. Letter from A. L. Patko to the U.S. Nuclear Regulatory Commission, “Submission of a Request for Authorization for the NAC-LWT Cask to Allow Shipment of the Dounreay Fuel Contents Supplementing the Certificate of Compliance (CoC) No. 9225,” November 10, 2011 (ADAMS Accession No. ML11333A049)

## 7.0 Packaging Operations

There are no changes to the packaging operations requirements currently approved for this authorization.

## 8.0 Fabrication and Maintenance

There are no changes to the fabrication and maintenance requirements currently approved for this authorization.

## CONDITIONS

The authorization is limited to the following condition:

A one-time authorization to ship the following special fuel assemblies:

- Three (3) 4x4 square EK-10 rod arrays (two with 16 rods; one with 15 rods)
    - $UO_2$-Mg fuel matrix/Al clad
    - Nominal 10 wt.% U-235
    - < 120 g U-235 per array
    - The maximum amount Uranium per assembly analyzed is 1400g
    - The maximum burnup analyzed is 20,000 MWd/MTU
    - The minimum cooling time is 28.3 years

- One (1) concentric tube ITR assembly (four square tubes)
    - U/Al alloy fuel/Al clad
    - Similar to DIDO assembly currently authorized, but uses four square "boxes" instead of cylindrical tubes
    - Nominal 90 wt.% U-235
    - < 170 g U-235 per assembly
    - The maximum Uranium per assembly analyzed is 220 g
    - The maximum burnup analyzed is 15,000 MWd/MTU
    - The minimum cooling time is 10 years

- One (1) hexagonal array (91 rods) TTR assembly
    - U/Al alloy fuel/Al clad

- Nominal 90 wt.% U-235
- < 400 g U-235 per assembly
- The maximum Uranium per assembly analyzed is 500g
- The maximum burnup analyzed is 60,000 MWd/MTU
- The minimum cooling time is 22.6 years

The assemblies will be transported in the currently certified MTR basket with the center basket opening blocked to prevent misloading.

The following additional conditions apply:

- All other conditions of CoC No. 9225 shall remain the same.
- This authorization shall expire on December 31, 2013.

**CONCLUSION**

CoC No. 9225 has been amended by letter for a one-time authorization to ship special fuel assemblies as specified above in a currently authorized MTR basket in the Model No. NAC-LWT package. This authorization expires December 31, 2013. 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 January 10, 2012.

2. PREAMBLE

a. This certificate is issued to certify that the package (packaging and contents) described in Item 5 below meets the applicable safety standards set forth in Title 10, Code of Federal Regulations, Part 71, “Packaging and Transportation of Radioactive Material.”

b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

a. ISSUED TO *(Name and Address)*

NAC International, Inc.
3930 East Jones Bridge Road
Norcross, GA 30092

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION

NAC International, Inc., application dated January 22, 2010.

4. CONDITIONS

This certificate is conditional upon fulfilling the requirements of 10 CFR Part 71, as applicable, and the conditions specified below.

5.
(a) Packaging

(1) Model No.: NAC-LWT

(2) Description

The LWT is a steel-encased, lead-shielded shipping cask. The cask is designed to transport various radioactive contents as listed in 5.(b)(1). The overall dimensions of the package, with impact limiters, are 232 inches long by 65 inches in diameter. The cask body is approximately 200 inches in length and 44 inches in diameter. The cask cavity is 178 inches long and 13.4 inches in diameter. The volume of the cavity is approximately 14.5 cubic feet.

The cask body consists of a 0.75-inch-thick stainless steel inner shell, a 5.75-inch-thick lead gamma shield, a 1.2-inch-thick stainless steel outer shell, and a neutron shield tank. The inner and outer shells are welded to a 4-inch-thick stainless steel bottom end forging. The cask bottom consists of a 3-inch-thick, 20.75-inch-diameter lead disk enclosed by a 3.5-inch-thick stainless steel plate and bottom end forging. The cask lid is 11.3-inch-thick stainless steel stepped design, secured to a 14.25-inch-thick ring forging with twelve 1-inch diameter bolts. The cask seal is a metallic O-ring. A second teflon O-ring and a test port are provided to leak test the seal. Other penetrations in the cask cavity include the fill and drain ports, which are sealed with port covers and O-rings.

The neutron shield tank consists of a 0.24-inch-thick stainless steel shell with 0.50-inch-thick end plates. The neutron shield region is 164 inches long and 5 inches thick. The neutron shield tank contains an ethylene glycol/water solution that is 1% boron by weight.

The cask is equipped with aluminum honeycomb impact limiters. The top impact limiter has an outside diameter of 65.25 inches and a maximum thickness of 27.8 inches. The bottom impact limiter has an outside diameter of 60.25 inches and maximum thickness of 28.3 inches. Both impact limiters extend 12 inches along the side of the cask body.

5.(a)(2) Description (continued)

The maximum weight of the package is 52,000 pounds and the maximum weight of the contents and basket is 4,000 pounds.

(3) Drawings

(i) The packaging is constructed in accordance with the following Nuclear Assurance Corporation Drawings:

| | |
|---|---|
| LWT 315-40-01, Rev. 7 | Cask Assembly |
| LWT 315-40-02, Rev. 24 (Sheets 1-2) | Body Assembly |
| LWT 315-40-03, Rev. 22 (Sheets 1-7)* | Transport Cask Body |
| LWT 315-40-04, Rev. 10 | Cask Lid Assembly |
| LWT 315-40-05, Rev. 10 | Upper Impact Limiter |
| LWT 315-40-06, Rev. 10 | Lower Impact Limiter |
| LWT 315-40-08, Rev. 18 (Sheets 1-5) | Cask Parts Detail |

* Packaging Unit Nos. 1, 2, 3, 4, and 5 are constructed in accordance with Drawing No. LWT 315-40-03, Rev. 6 (Sheets 1-6).

(ii) The fuel assembly baskets are constructed in accordance with the following Nuclear Assurance Corporation and NAC International Drawings:

| | |
|---|---|
| LWT 315-40-09, Rev. 2 | PWR Basket Spacer |
| LWT 315-40-10, Rev. 8 (Sheets 1-2) | PWR Basket |
| LWT 315-40-11, Rev. 2 | BWR Basket Assembly |
| LWT 315-40-12, Rev. 3 | Metal Fuel Basket Assembly |
| LWT 315-40-045, Rev. 6 | 42 MTR Element Base Module |
| LWT 315-40-046, Rev. 6 | 42 MTR Element Intermediate Module |
| LWT 315-40-047, Rev. 6 | 42 MTR Element Top Module |
| LWT 315-40-048, Rev. 3 | 42 MTR Element Cask Assembly |
| LWT 315-40-049, Rev. 6 | 28 MTR Element Base Module |
| LWT 315-40-050, Rev. 6 | 28 MTR Element Intermediate Module |
| LWT 315-40-051, Rev. 6 | 28 MTR Element Top Module |
| LWT 315-40-052, Rev. 3 | 28 MTR Element Cask Assembly |
| LWT 315-40-070, Rev. 6 | 7 Cell Basket TRIGA Base Module |
| LWT 315-40-071, Rev. 6 | 7 Cell Basket TRIGA Intermediate Module |
| LWT 315-40-072, Rev. 6 | 7 Cell Basket TRIGA Top Module |
| LWT 315-40-079, Rev. 6 | Transport Cask Assembly, 120 TRIGA Fuel Elements or 480 Cluster Rods |
| LWT 315-40-080, Rev. 4 | 7 Cell Poison Basket TRIGA Base Module |
| LWT 315-40-081, Rev. 4 | 7 Cell Poison Basket TRIGA Intermediate Module |
| LWT 315-40-082, Rev. 4 | 7 Cell Poison Basket TRIGA Top Module |
| LWT 315-40-083, Rev. 0 | Spacer, LWT Cask Assembly TRIGA Fuel |
| LWT 315-40-084, Rev. 4 | LWT Transport Cask Assy, 140 TRIGA Elements |

5.(a)(3)(ii) Drawings (continued)

| | |
|---|---|
| LWT 315-40-085, Rev. 1 | Axial Fuel and Cell Block Spacers, MTR, and TRIGA Fuel Baskets |
| LWT 315-40-090, Rev. 4 | 35 MTR Element Base Module |
| LWT 315-40-091, Rev. 4 | 35 MTR Element Intermediate Module |
| LWT 315-40-092, Rev. 4 | 35 MTR Element Top Module |
| LWT 315-40-094, Rev. 4 | 35 MTR Element Cask Assembly |
| LWT 315-40-096, Rev. 3 | Fuel Cluster Rod Insert, TRIGA Fuel |
| LWT 315-40-098, Rev. 6 (Sheets 1-3) | PWR/BWR Rod Transport Canister Assembly |
| LWT 315-40-099, Rev. 3 (Sheets 1-3) | Can Weldment, PWR/BWR Transport Canister |
| LWT 315-40-100, Rev. 4 (Sheets 1-5) | Lids, PWR/BWR Rod Transport Canister |
| LWT 315-40-101, Rev. 0 | 4 x 4 Insert, PWR/BWR Transport Canister |
| LWT 315-40-102, Rev. 2 | 5 x 5 Insert, PWR/BWR Transport Canister |
| LWT 315-40-103, Rev. 0 | Pin Spacer, PWR/BWR Transport Canister |
| LWT 315-40-104, Rev. 5 (Sheets 1-3) | LWT Cask Assembly, PWR/BWR Rod Transport Canister |
| LWT 315-40-105, Rev. 3 (Sheets 1-2) | PWR Insert, PWR/BWR Transport Canister |
| LWT 315-40-106, Rev. 1 (Sheets 1-3) | MTR Plate Canister, LWT Cask |
| LWT 315-40-108, Rev. 1 (Sheets 1-3) | 7 Cell Basket, Top Module, DIDO Fuel |
| LWT 315-40-109, Rev. 1 (Sheets 1-3) | 7 Cell Basket, Intermediate Module, DIDO Fuel |
| LWT 315-40-110, Rev.1 (Sheets 1-3) | 7 Cell Basket, Base Module, DIDO Fuel |
| LWT 315-40-111, Rev. 2 | LWT Transport Cask Assy DIDO Fuel |
| LWT 315-40-113, Rev. 0 | Spacer, Top Module DIDO Fuel |
| LWT 315-40-120, Rev. 2 (Sheets 1-3) | Top Module, General Atomics IFM, LWT Cask |
| LWT 315-40-123, Rev. 1 (Sheets 1-2) | Spacer, General Atomics IFM, LWT Cask |
| LWT 315-40-124, Rev. 1 | Transport Cask Assembly, General Atomics IFM, LWT Cask |
| LWT 315-40-125, Rev. 3 (Sheets 1-3) | Transport Cask Assembly, Framatome/EPRI, LWT Cask |
| LWT 315-40-126, Rev. 2 (Sheets 1-2) | Weldment, Framatome/EPRI, LWT Cask |
| LWT 315-40-127, Rev. 2 (Sheets 1-2) | Spacer Assembly, TPBAR Shipment |
| LWT 315-40-129, Rev. 1 | Canister Body Assembly, Failed Fuel Can, PULSTAR |
| LWT 315-40-130, Rev. 1 | Assembly, Failed Fuel Can, PULSTAR |
| LWT 315-40-133, Rev. 1 (Sheets 1-2) | Transport Cask Assembly, PULSTAR Shipment, LWT Cask |
| LWT 315-40-134, Rev. 1 | Body Weldment, Screened Fuel Can, PULSTAR Fuel |
| LWT 315-40-135, Rev. 1 | Assembly, Screened Fuel Can, PULSTAR Fuel |
| LWT 315-40-139, Rev. 1 | Transport Cask Assembly, ANSTO Fuel |
| LWT 315-40-140, Rev. 1 (Sheets 1-2) | Weldment, 7 Cell Basket, Top Module, ANSTO Fuel |

5.(a)(3)(ii) Drawings (continued)

| | |
|---|---|
| LWT 315-40-141, Rev. 1 (Sheets 1-2) | Weldment, 7 Cell Basket, Intermediate Module, ANSTO Fuel |
| LWT 315-40-142, Rev. 1 (Sheets 1-2) | Weldment, 7 Cell Basket, Base Module, ANSTO Fuel |
| LWT 315-40-145, Rev. 0 (Sheets 1-2) | Irradiated Hardware, Lid Spacer, LWT Cask |
| LWT 315-40-148, Rev. 0 | LWT Transport Cask Assembly, ANSTO-DIDO Combination Basket |

5.(b) Contents

(1) Type and form of material

All contents listed include both unirradiated and irradiated conditions.

(i) PWR fuel assemblies. The maximum fuel assembly weight is 1650 pounds, the maximum average burnup is 35,000 MWd/MTU, the minimum cool time is 2 years, and the maximum initial fuel pin pressure at 70°F is 565 psig. The fuel assemblies consist of uranium dioxide pellets within zirconium alloy type cladding, with the specifications listed below, and with fuel rod pitch, rod diameter, clad thickness, and pellet diameter as described in Table 1.2-5, of the application.

| Fuel Type | No. Fuel Rods | Max. Initial Uranium Enrichment (wt % U-235) | Max. Initial Uranium Mass (MTU) | Max. Active Fuel Length (in.) |
|---|---|---|---|---|
| B&W 15x15 | 208 | 3.5 | 0.4750 | 144.0 |
| B&W 17x17 | 264 | 3.5 | 0.4658 | 143.0 |
| CE 14x14 | 176 | 3.7 | 0.4037 | 137.0 |
| CE 16x16 | 236 | 3.7 | 0.4417 | 150.0 |
| WE 14x14 Std | 179 | 3.7 | 0.4144 | 145.2 |
| WE 14x14 OFA | 179 | 3.7 | 0.3612 | 144.0 |
| WE 15x15 | 204 | 3.5 | 0.4646 | 144.0 |
| WE 17x17 Std | 264 | 3.5 | 0.4671 | 144.0 |

5.(b)(1)(i) PWR fuel assemblies. (continued)

| | | | | |
|---|---|---|---|---|
| WE 17x17 OFA | 264 | 3.5 | 0.4282 | 144.0 |
| Ex/ANF 14x14 WE | 179 | 3.7 | 0.3741 | 144.0 |
| Ex/ANF 14x14 CE | 176 | 3.7 | 0.3814 | 134.0 |
| Ex/ANF 15x15 WE | 204 | 3.7 | 0.4410 | 144.0 |
| Ex/ANF 17x17 WE | 264 | 3.5 | 0.4123 | 144.0 |

(ii) BWR fuel assemblies. The maximum fuel assembly weight is 750 pounds, the maximum average burnup is 30,000 MWd/MTU, the minimum cool time is 2 years, and the maximum initial fuel pin pressure at 70°F is 565 psig. The fuel assemblies consist of uranium dioxide pellets within zirconium alloy type cladding, with the specifications listed below, and with fuel rod pitch, rod diameter, clad thickness, and pellet diameter as described in Table 1.2-6, of the application.

| Fuel Type | No. Fuel Rods | No. Water Rods | Max. Initial Uranium Enrichment (wt % U-235) | Max. Initial Uranium Mass (MTU) | Max. Active Fuel Length (in.) |
|---|---|---|---|---|---|
| GE 7x7 | 49 | 0 | 4.0 | 0.1923 | 146 |
| GE 8x8-1 | 63 | 1 | 4.0 | 0.1880 | 146 |
| GE 8x8-2 | 62 | 2 | 4.0 | 0.1847 | 150 (1) |
| GE 8x8-4 | 60 | 4 | 4.0 | 0.1787 | 150 (1,2) |
| GE 9x9 | 74 | 2 | 4.0 | 0.1854 | 150 (1,3,4) |
| | 79 | 2 | 4.0 | 0.1979 | 150 (1,4) |
| Ex/ANF 7x7 | 49 | 0 | 4.0 | 0.1960 | 144 |
| Ex/ANF 8x8-1 | 63 | 1 | 4.0 | 0.1764 | 145.2 |
| Ex/ANF 8x8-2 | 62 | 2 | 4.0 | 0.1793 | 150 |
| Ex/ANF 9x9 | 79 | 2 | 4.0 | 0.1779 | 150 |
| | 74 | 2 | 4.0 | 0.1666 | 150 (3) |

(1) Six-inch natural uranium blankets on top and bottom.
(2) One large water hole - 3.2 cm ID, 0.1 cm thickness.
(3) Two large water holes occupying seven fuel rod locations - 2.5 cm ID, 0.07 cm thickness.
(4) Shortened active fuel length in some rods.

5.(b)(1) Type and form of material (continued)

(iii) Deleted.

(iv) MTR fuel elements composed of U-Al, $U_3O_8$-Al, or $U_3Si_x$-Al positioned within the MTR fuel basket specified in 5.(a)(3)(ii). Loose fuel plates must meet the requirements of the MTR fuel element content tables and must be loaded into an MTR plate canister prior to shipment. The fuel elements are composed of aluminum clad plates, with initial uranium enrichment up to 94.0 weight percent U-235. The maximum burnup and the minimum cool time shall be consistent with the decay heat limits in Item 5.(b)(2)(iv) and shall be determined using the operating procedures in Section 7.1.5 of the application.

NISTR MTR fuel elements specifications are listed in Item 5.(b)(1)(iv)(a), generic MTR fuel elements are listed in Item 5.(b)(1)(iv)(b), and expanded fuel specifications applicable to LEU MTR fuel (up to 25.0 wt %$^{235}$U) are listed in Items 5.(b)(1)(iv)(c) and 5.(b)(1)(iv)(d).

(a) NISTR MTR Fuel Content Description

| Parameter | Plate | Plate (cut in half) |
|---|---|---|
| Enrichment, wt % $^{235}$U | ≤94 | |
| Number of fuel plates | ≤17 | ≤34 |
| $^{235}$U content per plate | ≤22 | ≤11 |
| Plate thickness (cm) | ≥0.115 | |
| Clad Thickness (cm) | ≥0.02 | |
| Active fuel width (cm) | ≤6.6 | |
| Active fuel height (cm) | ≥54 cm | 27 to 30 |
| Maximum $^{235}$U content per element (g) | ≤380 | |

5.(b)(1) Type and form of material (continued)

(iv) (b) Generic MTR Fuel Content Description

| Parameter | Limiting Values[2] | | | | | |
|---|---|---|---|---|---|---|
| Enrichment, wt. % $^{235}U$ | ≤94 | | | | | |
| Number of fuel plates | ≤23 | ≤19 | ≤23[1] | ≤17 | ≤19 | ≤23 |
| $^{235}U$ content per plate | ≤18 | ≤20 | ≤20[1] | ≤21 | ≤21 | ≤16.5 |
| Plate thickness (cm) | ≥0.115 | ≥0.115 | ≥0.123[1] | ≥0.115 | ≥.200 | ≥0.115 |
| Clad Thickness (cm) | ≥0.02 | | | | | |
| Active fuel width (cm) | ≤6.6 | ≤6.6 | ≤6.6 | ≤6.6 | ≤6.6 | ≤7.3 |
| Active fuel height (cm) | ≥56 | | | | | |
| $^{235}U$ content per element (g) | ≤380[2] | | | | | |

Notes:

1. HEU (>90 wt% $^{235}U$ enriched) MTR fuel having 23 plates with up to 20 g of $^{235}U$ per plate, with a minimum plate thickness of 0.123 cm, must have at least 2.0 cm of non-fuel material at the ends of each element. This fuel may also be loaded up to 460 g $^{235}U$ per element.

2. At enrichments ≤25 wt% $^{235}U$, MTR fuel elements with extended fuel characteristics may be loaded with the specifications defined in 5.(b)(1)(iv)(c).

5.(b)(1) Type and form of material (continued)

(iv) (c) Expanded LEU MTR Fuel Content Description

| Parameter | Base | ≤7.0 cm Active Fuel Width | | | ≤7.1 cm Active Fuel Width | | ≤7.15 cm Active Fuel Width | | |
|---|---|---|---|---|---|---|---|---|---|
| Enrichment, wt. % $^{235}U$ | ≤25 | ≤25 | | | ≤25 | | ≤25 | | |
| Number of fuel plates | ≤23 | ≤23 | | | ≤17 | ≤23 | ≤22 | ≤23 | ≤23 |
| $^{235}U$ content per plate | ≤22 | ≤22 | ≤22 | ≤21.5 | ≤22 | | ≤22 | ≤21.5 | ≤22 |
| Plate thickness (cm) | ≥0.115 | ≥0.119 | ≥0.115 | ≥0.115 | ≥0.115 | ≥0.200 | ≥0.119 | | |
| Clad Thickness (cm) | ≥0.02 | | | | | | | | |
| Active fuel width (cm) | ≤6.6 | ≤7.0 | | | ≤7.1 | | ≤7.15 | | |
| Active fuel height (cm) | ≥56 | ≥56 | ≥63 | ≥56 | ≥56 | | ≥56 | ≥56 | ≥61 |
| $^{235}U$ content per element (g) | ≤420 | ≤470 | | | ≤470 | | ≤470 | | |

5.(b)(1) Type and form of material (continued)

(iv) (d) Expanded LEU MTR Fuel Content Description for High Fissile Material Mass

| Parameter | Limiting Value |
|---|---|
| Enrichment, wt.% $^{235}U$ | ≤25 |
| Number of fuel plates | ≤23 |
| $^{235}U$ content per plate (g) | ≤32 |
| Plate thickness (cm) | ≥0.115 |
| Clad thickness (cm) | ≥0.02 |
| Active fuel width (cm) | ≤7.3 |
| Active fuel height (cm) | ≥56 |
| $^{235}U$ content per element (g) | ≤640 |

(v) Metallic fuel rods containing natural enrichment uranium pellets with aluminum cladding 0.080-inches thick. The fuel pellet diameter is 1.36 inches and the maximum fuel rod length is 120.5 inches. The maximum weight of uranium per rod is 54.5 kg with a maximum average burnup of 1,600 MWd/MTU and a minimum cooling time of one year.

(vi) TRIGA damaged and undamaged fuel elements. TRIGA fuel elements that have a cladding breach that allows the escape of gas or intrusion of water are considered damaged and will be loaded and transported in a sealed damaged fuel can.

5.(b)(1) Type and form of material (continued)

(vi) (a) TRIGA fuel elements acceptable for loading in the poisoned TRIGA basket and meeting the following specifications:

| | TRIGA HEU (Notes 1, 2, 6, & 7) | TRIGA LEU (Notes 1, 2, 6, & 7) | TRIGA LEU (Notes 1, 2, 6, & 7) |
|---|---|---|---|
| Fuel Form | Clad U-ZrH rod | Clad U-ZrH rod | Clad U-ZrH rod |
| Maximum Element Weight, lbs | 13.2 | 13.2 | 13.2 |
| Maximum Element Length, in | 47.74 | 47.74 | 47.74 |
| Element Cladding | Stainless Steel | Stainless Steel | Aluminum |
| Clad Thickness, in | 0.02 | 0.02 | 0.03 |
| Active Fuel Length, in | 15 | 15 | 14-15 (Note 4) |
| Element Diameter, in | 1.478 max. | 1.478 max. | 1.47 max. |
| Fuel Diameter, in | 1.435 max. | 1.435 max. | 1.41 max. |
| Maximum Initial U Content/Element, kilograms | 0.196 | 0.845 | 0.205 |
| Maximum Initial $^{235}U$ Mass, grams | 137 | 169 | 41 |
| Maximum Initial $^{235}U$ Enrichment, weight percent | 70 | 20 | 20 |
| Zirconium Mass, grams (Note 5) | 2060 | 1886 – 2300 | 2300 |
| Hydrogen to Zirconium Ratio, max. (Note 5) | 1.6 | 1.7 | 1.0 |
| Maximum Average Burnup, MWd/MTU | 460,000 (80% $^{235}U$) | 151,100 (80% $^{235}U$) | 151,100 (80% $^{235}U$) |
| Minimum Cooling Time | 90 days (Note 3) | 90 days (Note 3) | 90 days (Note 3) |

Notes:
1. Mixed TRIGA LEU and HEU contents authorized.
2. TRIGA Standard, instrumented and fuel follower control rod type elements authorized.
3. Maximum decay heat of any element is 7.5 watts.
4. Aluminum clad fuel with 14 inch active fuel is solid and has no central hole with a zirconium rod.
5. Zirconium mass and H/Zr ratio apply to the fuel material (U-Zr-$H_x$) and do not include the center zirconium rod.
6. Listed TRIGA fuel elements have a 0.225-inch diameter zirconium rod in the center.
7. Dimensions listed are as-fabricated (unirradiated) nominal values.

5.(b)(1) Type and form of material (continued)

(vi) (b) TRIGA fuel elements acceptable for loading in the nonpoisoned TRIGA basket and meeting the following specifications:

| | TRIGA HEU (Notes 1, 2, & 6) | TRIGA LEU (Notes 1, 2, & 6) | TRIGA LEU (Notes 1, 2, & 6) |
|---|---|---|---|
| Fuel Form | Clad U-ZrH rod (Note 4) | Clad U-ZrH rod (Note 4) | Clad U-ZrH rod (Note 4) |
| Maximum Element Weight, lbs | 13.2 | 13.2 | 13.2 |
| Maximum Element Length, in | 47.74 | 47.74 | 47.74 |
| Element Cladding | Stainless Steel | Stainless Steel | Aluminum |
| Minimum Clad Thickness, in | 0.01 | 0.01 | 0.01 |
| Maximum Element Diameter, in | 1.5 max. | 1.5 max. | 1.5 max. |
| Active Fuel Length, in | 15 | 15 | 15 |
| Maximum Initial U Content/Element, kilograms | 0.196 | 0.845 | 0.205 |
| Maximum Initial $^{235}U$ Mass, grams | 137 | 169 | 41 |
| Maximum Initial $^{235}U$ Enrichment, weight percent | 70 | 20 | 20 |
| Hydrogen to Zirconium Ratio, max. (Note 5) | 2.0 | 2.0 | 2.0 |
| Maximum Average Burnup, MWd/MTU | 460,000 (80% $^{235}U$) | 151,100 (80% $^{235}U$) | 151,100 (80% $^{235}U$) |
| Minimum Cooling Time | 90 days (Note 3) | 90 days (Note 3) | 90 days (Note 3) |

Notes:
1. Mixed TRIGA LEU and HEU contents authorized.
2. TRIGA Standard, instrumented and fuel follower control rod type elements authorized.
3. Maximum decay heat of any element is 7.5 watts.
4. Element may contain a zirconium rod in the center.
5. H/Zr ratio applies to the fuel material (U-Zr-$H_x$) and does not include the center zirconium rod.
6. Dimensions listed are as-fabricated (unirradiated) nominal values.

5.(b)(1) Type and form of material (continued)

(vi) (c) General Atomics TRIGA fuel elements acceptable for loading in the nonpoisoned TRIGA basket and meeting the following specifications:

| | TRIGA HEU (Notes 1, 2, & 6) | | TRIGA LEU (Notes 1, 2, & 6) | | TRIGA LEU (Notes 1, 2, & 6) |
|---|---|---|---|---|---|
| Fuel Form | Clad U-ZrH rod (Note 4) | | Clad U-ZrH rod (Note 4) | | Clad U-ZrH rod (Note 4) |
| Maximum Element Weight, lbs | 13.2 | | 13.2 | | 13.2 |
| Maximum Element Length, in | 47.74 | | 47.74 | | 47.74 |
| Element Cladding | Stainless Steel | | Stainless Steel | | Aluminum |
| Minimum Clad Thickness, in | 0.01 | | 0.01 | | 0.01 |
| Maximum Element Diameter, in | 1.5 max. | | 1.5 max. | | 1.5 max. |
| Active Fuel Length, in | 15 | | 15 | | 15 |
| Maximum Initial U Content/Element, kilograms | 0.198 | 0.186 | 0.845 | 1.447 | 0.205 |
| Maximum Initial $^{235}$U Mass, grams | 138 | 175[7,8] | 169 | 275[7,8] | 41 |
| Maximum Initial $^{235}$U Enrichment, weight percent | 71 | 95[7,8] | 25 | 25[7,8] | 25 |
| Hydrogen to Zirconium Ratio, max. (Note 5) | 2.0 | | 2.0 | | 2.0 |
| Maximum Average Burnup, MWd/MTU | 460,000 (80% $^{235}$U) | 583,000 (80% $^{235}$U) | 151,100 (80% $^{235}$U) | | 151,100 (80% $^{235}$U) |
| Minimum Cooling Time | 90 days (Note 3) | | 90 days (Note 3) | | 90 days (Note 3) |

Notes:

1. Mixed TRIGA LEU and HEU fuel elements and LEU and HEU TRIGA fuel cluster rod contents authorized.
2. TRIGA Standard, instrumented and fuel follower control rod type elements authorized.
3. Maximum decay heat of any element is 7.5 watts.
4. Element may contain a zirconium rod in the center.
5. H/Zr ratio applies to the fuel material (U-Zr-$H_x$) and does not include the center zirconium rod.
6. Dimensions listed are as-fabricated (unirradiated) nominal values.
7. Limited to loading in top and bottom basket modules only.
8. Limited to a maximum of three elements per basket module cell.

5.(b)(1) Type and form of material (continued)

(vii) (a) TRIGA fuel cluster rods. TRIGA HEU fuel cluster rods have a maximum average burnup of 600,000 MWd/MTU (80% $^{235}$U depletion) and a minimum cooling time of 90 days. TRIGA LEU fuel cluster rods have a maximum average burnup of 140,000 MWd/MTU (80% $^{235}$U depletion) and a minimum cooling time of 90 days. TRIGA fuel cluster rods must meet the following specifications prior to irradiation:

| | TRIGA Fuel Cluster Rods | |
|---|---|---|
| | HEU | LEU |
| Fuel Form | Clad U-ZrH rod | |
| Maximum Rod Weight, lbs | 1.5 | |
| Maximum Rod Length, in | 31 | |
| Rod Cladding | Incoloy 800 | |
| Minimum Clad Thickness, in | 0.015 | |
| Maximum Active Fuel Length, in | 22.5 | |
| Maximum Fuel Pellet Diameter, in | 0.53 | |
| Maximum U Content/Rod, grams | 48.6 | 289.5 |
| Maximum $^{235}$U Mass, grams | 45.4 | 55.0 |
| Maximum $^{235}$U Enrichment, weight percent | 93.3 | 20 |
| Maximum Zirconium Mass, grams | 421 | 357 |
| Hydrogen to Zirconium Ratio, max. | 1.7 | |

NOTE: TRIGA fuel cluster rods that have a cladding breach that allows the escape of gas or intrusion of water are considered damaged and will be loaded and transported in a sealed damaged fuel can.

5.(b)(1) Type and form of material (continued)

(vii) (b) General Atomics TRIGA fuel cluster rods. TRIGA HEU fuel cluster rods have a maximum average burnup of 600,000 MWd/MTU (80% $^{235}U$ depletion) and a minimum cooling time of 90 days. TRIGA LEU fuel cluster rods have a maximum average burnup of 140,000 MWd/MTU (80% $^{235}U$ depletion) and a minimum cooling time of 90 days. TRIGA fuel cluster rods must meet the following specifications prior to irradiation:

| | TRIGA Fuel Cluster Rods | |
|---|---|---|
| | HEU | LEU |
| Fuel Form | Clad U-ZrH rod | |
| Maximum Rod Weight, lbs | 1.5 | |
| Maximum Rod Length, in | 31 | |
| Rod Cladding | Incoloy 800 | |
| Minimum Clad Thickness, in | 0.015 | |
| Maximum Active Fuel Length, in | 22.5 | |
| Maximum Fuel Pellet Diameter, in | 0.53 | |
| Maximum U Content/Rod, grams | 48.6 | 289.5 |
| Maximum $^{235}U$ Mass, grams | 46.5 | 55.0 |
| Maximum $^{235}U$ Enrichment, weight percent | 93.3 | 20 |
| Maximum Zirconium Mass, grams | 421 | 357 |
| Hydrogen to Zirconium Ratio, max. | 1.7 | |

NOTE: TRIGA fuel cluster rods that have a cladding breach that allows the escape of gas or intrusion of water are considered damaged and will be loaded and transported in a sealed damaged fuel can.

(viii) High burnup PWR rods, consisting of uranium dioxide pellets within zirconium alloy type cladding. The maximum uranium enrichment is 5 weight percent U-235, the maximum active fuel length is 150 inches, and the maximum pellet diameter is 0.3765 inches. The maximum burnup is 80,000 MWd/MTU, and the minimum cool time is 150 days.

5.(b)(1) Type and form of Material (continued)

(ix) High burnup BWR rods, consisting of uranium dioxide pellets within zirconium alloy type cladding. The maximum uranium enrichment is 5 weight percent U-235, the maximum active fuel length is 150 inches, and the maximum pellet diameter is 0.490 inch. The maximum burnup is 80,000 MWd/MTU and the minimum cool time is between 150 - 270 days, as specified in the table below:

| BWR Fuel Type Array Size | Burnup, b (GWd/MTU) | Minimum Cool Time (days) |
|---|---|---|
| 7 x 7 | $b \leq 60$<br>$60 < b \leq 70$<br>$70 < b \leq 80$ | 210<br>240<br>270 |
| 8 x 8[1] | $b \leq 80$ | 150 |

Note 1: Includes rods from all larger BWR assembly arrays (e.g., 9 x 9, 10 x 10)

(x) Intact or degraded clad DIDO fuel elements composed of U-Al, $U_3O_8$-Al, or $U_3Si_x$-Al plates fabricated into four concentric tubes of varying diameters. The fuel elements have an initial enrichment up to 94.0 weight percent U-235. Maximum degraded clad allowable per element is ≤ 5% surface area. Degraded clad DIDO fuel elements are to be loaded into an aluminum damaged fuel can (DFC) per Figure 1.2.3-18 of the application. The fuel elements shall have the specifications listed below:

| Parameter | LEU[(1)] | MEU[(1)] | HEU[(1)] |
|---|---|---|---|
| Maximum $^{235}U$ content per Element | ≤ 190 g | ≤ 190 g | ≤ 190 g |
| Maximum Uranium content per Element | ≤ 1000 g | ≤ 475.0 g | ≤ 211.1g |
| Minimum Fuel Tube Thickness | 0.130 cm | 0.130 cm | 0.130 cm |
| Minimum Clad Thickness | 0.025 cm | 0.025 cm | 0.025 cm |
| Maximum Outer Diameter | 9.535 cm | 9.535 cm | 9.535 cm |
| Minimum Inner Diameter | 5.88 cm | 5.88 cm | 5.88 cm |
| Minimum Initial Enrichment | 19 wt% $^{235}U$ | 40 wt% $^{235}U$ | 90 wt% $^{235}U$ |

1 The maximum burnup and minimum cool time shall be consistent with the decay heat limits in Item 5.(b)(2)(xi)(a) and (b) and shall be determined using the operating procedures in Section 7.1.4 of the application.

5.(b)(1) Type and form of material (continued)

(xi) General Atomics (GA) Irradiated Fuel Material (IFM) consisting of two separate types of fuel materials: (a) High Temperature Gas Cooled Reactor (HTGR); and (b) Reduced-Enrichment Research and Test Reactor (RERTR) type TRIGA fuel entities.

(a) GA HTGR IFM comprised of four forms: fuel particles (kernels), fuel particles (coatings), fuel compacts (rods), and fuel pebbles. Fuel particles (kernels) are solid, spheridized, high-temperature sintered fully-densified, ceramic kernel substrate, composed of $UO_2$, $UCO_2$, $(Th,U)C_2$, or $(Th,U)O_2$. Fuel particles (coatings) are solid , spheridized, isotropic, discrete multi-layered fuel particle coatings with chemical composition including pyrolitic-carbon (PyC) and silicon carbide (SiC). Fuel compacts (rods) are multi-coated ceramic fuel particles, bound in solid, cylindrical, injection molded, high-temperature heat-treated compacts which are composed of carbonized graphite shim, coke, and graphite powder. Fuel pebbles are multi-coated fuel particles, bound in solid, spherical injection-molded, high-temperature heat-treated pebbles composed of carbonized graphite shim, coke and graphite powder. Initial enrichment of the HTGR IFM varies from 10.0 to 93.15 wt% $^{235}U$.

(b) GA RERTR IFM comprised of irradiated TRIGA fuel elements which contain three distinct mass loadings of uranium of 20, 30, and 45 wt% U. The average mass of the fuel portion of the elements is 551 g with a maximum initial enrichment of 19.7 wt% U-235.

GA IFM content description:

| | GA HTGR IFM | GA RERTR IFM |
|---|---|---|
| Fuel material | $UC_2$, UCO, $UO_2$ $(Th,U)C_2$, $(Th,U)O_2$ | U-ZrH metal alloy |
| Maximum fuel weight, lbs | 23.52 | 23.73 |
| Maximum overall length, in | n/a | 29.92 |
| Maximum active fuel length, in | n/a | 22.05 |
| Fuel rod cladding | n/a | Incoloy 800 |
| Maximum Uranium, kg U | 0.21 | 3.86 |
| Maximum initial $^{235}U$, wt% | 93.15 | 19.7 |
| Maximum Activity, Ci | 483 | 2920 |

5.(b)(1) Type and form of material (continued)

(xii) Tritium-producing burnable absorber rods (TPBARs), as described in Section 1.2.3.6 of the application. Each TPBAR is approximately 153 inches in length and 0.381 inches in diameter and is stainless steel clad. The TPBARs contain lithium aluminate annular pellets, with an inner zircaloy liner and an outer nickel-plated zircaloy tube. Each TPBAR contains a maximum of 1.2 grams tritium. The minimum cool time is 30 days.

(xiii) Intact or damaged PULSTAR fuel elements, including fuel debris, pieces and nonfuel components of PULSTAR fuel assemblies as specified below.

| Description | Value |
|---|---|
| Maximum Pellet Diameter (inch) | 0.423 |
| Minimum Element (Rod) Cladding Thickness (inch) | 0.0185 |
| Minimum Element (Rod) Diameter (inch) | 0.470 |
| Maximum Active Fuel Height (inch) | 24.1 |
| Nominal Element (Rod) Length (inch) | 26.2 |
| Nominal Assembly Length (inch) | 38 |
| Maximum Assembly or Loaded Can Weight (lb) | 80 |
| Maximum PULSTAR Can Content Weight (lb) | 39.6 |
| Maximum Enrichment (wt % $^{235}$U) | 6.5 |
| Maximum $^{235}$U Content per Element (g) | 33 |
| No. of Elements (Rods) per Assembly | 25 |
| No. of Elements (Rods) per Can[1] | ≤25 |
| Maximum Depletion (% $^{235}$U) | 45 |
| Minimum Cooling Time (yrs) | 1.5 |
| Maximum Heat Load per Assembly (W) | 30 |
| Maximum Heat Load per Element (W) | 1.2 |

[1] Damaged PULSTAR fuel elements, including fuel debris, pieces and nonfuel components of PULSTAR fuel assemblies must be loaded into a PULSTAR can. The contents of a PULSTAR can are restricted to the equivalent of the fuel material in 25 intact PULSTAR fuel elements and of the displaced volume of 25 intact PULSTAR fuel elements.

5.(b)(1) Type and form of material (continued)

(xiv) Intact or degraded clad ANSTO fuel consisting of spiral fuel assemblies and MOATA plate bundles. Maximum degraded clad allowable per element is ≤ 5% surface area. Degraded clad ANSTO fuel elements are to be loaded into an aluminum damaged fuel can (DFC) per Figure 1.2.3-18 of the application.

Spiral fuel assemblies consist of 10 curved uranium-aluminum alloy fuel plates between an inner and an outer aluminum shell, with the following fuel parameters:

| Parameter | Limiting Values |
|---|---|
| Number of fuel plates per assembly | 10 |
| Maximum $^{235}U$ content per assembly (g) | 160 |
| Maximum enrichment (wt % $^{235}U$) | 95 |
| Maximum assembly weight (lb) | 18 |
| Minimum plate thickness (cm) | 0.124 |
| Minimum active fuel height (cm) | 59.075 |

MOATA plate bundles consist of uranium-aluminum alloy fuel plates with aluminum cladding, with the following specifications:

| Parameter | Limiting Values |
|---|---|
| Maximum number of fuel plates per assembly | 14 |
| Maximum $^{235}U$ content per plate (g) | 22.3 |
| Maximum enrichment (wt % $^{235}U$) | 92 |
| Maximum plate spacer thickness (cm) | 0.18 |
| Maximum active fuel width (cm) | 7.32 |
| Maximum bundle weight (lb) | 18 |

(xv) Segmented TPBARs and associated segmentation debris resulting from post-irradiation examination, as described in Section 1.2.3.6 of the application. Each equivalent TPBAR contains a maximum of 1.2 grams of tritium. The minimum cool time is 90 days.

(xvi) Solid, irradiated and contaminated fuel assembly structural or reactor internal component hardware, which may include fissile material, provided the quantity of fissile material does not exceed a Type A quantity and qualifies as an exempt quantity under 10 CFR 71.15.

(xvii) PWR MOX (mixed oxide) undamaged fuel rods consisting of uranium and plutonium and plutonium dioxide pellets within zirconium alloy type cladding. The plutonium enrichment is 7.0 weight percent maximum and 2.0 weight percent minimum, the maximum active fuel rod length is 153.5 inches, and the maximum pellet diameter is 0.3765 inch. The maximum burnup is 62,500 MWd/MTU and the minimum cool time is 90 days.

5.(b)(2) Maximum quantity of material per package

Not to exceed 4,000 pounds, including contents and fuel assembly basket or other internal support structure.

(i) For the contents described in Item 5.(b)(1)(i): one PWR assembly positioned within the PWR fuel assembly basket. Maximum decay heat not to exceed 2.5 kilowatts per PWR assembly.

(ii) For the contents described in Item 5.(b)(1)(ii): two BWR assemblies positioned within the BWR fuel assembly basket. Maximum decay heat not to exceed 1.1 kilowatts per BWR assembly.

(iii) Deleted.

(iv) For MTR fuel elements as described in Item 5.(b)(1)(iv):

Up to 42 fuel elements positioned within the MTR fuel assembly basket (7 fuel elements per basket module). Each of the MTR basket cell openings may contain a loose plate canister. The contents of each loose plate canister are limited to the number of fuel plates, dimensions, and masses that are equivalent to an intact MTR fuel element, as specified in Item 5.(b)(1)(iv).

(a) The maximum decay heat is not to exceed 1.26 kilowatts per package, with each MTR fuel assembly basket module not to exceed 210 watts.

(b) HEU, MEU, and LEU MTR fuel elements with decay heat not exceeding 30 watts per element may be loaded in any basket position.

(c) Mixed HEU, MEU, and LEU MTR contents, with decay heat limits as specified above, are authorized.

(d) MTR fuel elements with degraded or mechanically damaged cladding are authorized, provided the total surface area of through-clad corrosion and/or mechanical damage does not exceed 5% of the total surface area of the damaged element.

(e) For HEU-MTR fuel elements only, the center fuel element in any basket module is not to exceed 120 watts. The two exterior fuel elements vertically in-line with the center assembly for transport are not to exceed 70 watts.

(f) MTR fuel elements containing more than 470 g $^{235}$U (more than 22 g $^{235}$U per plate) are limited to up to four elements loaded in basket positions 4, 5, 6, and 7 of a seven-element basket per Figure 7.1-1 of the application. Basket positions 1, 2, and 3 are to be blocked by spacer hardware.

5.(b)(2) Maximum quantity of material per package (continued)

(v) For the contents described in Item 5.(b)(1)(v): up to 15 intact metallic fuel rods positioned within the appropriate basket. Maximum decay heat not to exceed 0.036 kilowatts per rod. Total weight of all rods not to exceed 1,805 pounds.

(vi) For failed metallic fuel rods of the type described in Item 5.(b)(1)(v):

(a) Up to six canisters containing one defective metallic fuel rod per canister. The canisters are 2.75-inch I.D. failed fuel rod canisters as shown on Nuclear Assurance Corporation Drawing No. 340-108-D2, Rev. 10, and are placed in a six-hole liner as shown on Nuclear Assurance Corporation Drawing No. 315-040-43, Rev. 1. The maximum decay heat load for a defective metallic fuel rod is limited to 5 watts; or

(b) Up to three canisters containing either up to three defective metallic fuel rods per canister or up to 10 failed fuel filters per canister. The canisters are 4.00-inch I.D. failed fuel rod canisters as shown on Nuclear Assurance Corporation Drawing No. 340-108-D1, Rev. 10, and are placed in a three-hole basket as shown on Nuclear Assurance Corporation Drawing No. 315-40-12, Rev. 3. The weight of the filters is limited to 125 pounds per canister. For canisters containing fuel rods, the maximum decay heat load is 15 watts per canister; and for canisters containing filters, the maximum decay heat load is 5 watts per canister.

5.(b)(2) Maximum quantity of material per package (continued)

(vii)(a) For TRIGA fuel elements as described in Item 5.(b)(1)(vi)(a):

Up to 140 intact fuel elements in the TRIGA fuel package with poisoned baskets. Up to four fuel elements per basket cell and up to seven cells per basket may be loaded. Damaged TRIGA fuel elements or fuel element debris (up to a total of two equivalent elements) shall be transported in a sealed damaged fuel can (one damaged fuel can per cell). The sealed cans are to be in accordance with NAC International Drawing Nos. 315-40-086, 315-40-087, and 315-40-088.

Mixed intact and damaged fuel contents and fuel debris are authorized. Base and top fuel basket modules may contain intact fuel elements or sealed damaged fuel cans containing damaged fuel and fuel debris. A maximum of seven damaged fuel cans is authorized per top and base basket modules with a maximum of 14 per package. Intermediate fuel basket modules may contain only intact TRIGA fuel elements.

The maximum decay heat shall not exceed 7.5 watts per TRIGA fuel element (or equivalent for damaged fuel) and 1050 watts per package. The cask and baskets must be configured as shown in NAC International Drawing Nos. 315-40-084, 315-40-080, 315-40-081, and 315-40-082.

(vii)(b) For TRIGA fuel elements as described in Item 5.(b)(1)(vi)(b):

Up to 120 intact fuel elements in the TRIGA fuel package with non-poisoned basket. Up to four fuel elements per basket cell only loaded in the six periphery cells. TRIGA fuel elements or sealed cans may not be loaded in the center cell of the non-poisoned basket. Damaged TRIGA fuel elements or fuel debris (up to two equivalent elements) shall be transported in a sealed damaged fuel can (one damaged fuel can per cell). The sealed cans are to be in accordance with NAC International Drawing Nos. 315-40-086, 315-40-087, and 315-40-088.

Mixed intact and damaged fuel contents and fuel debris are authorized. Base and top fuel basket modules may contain intact fuel elements or sealed damaged fuel cans containing damaged fuel or fuel debris. A maximum of six damaged fuel cans is authorized only in the periphery cells per top and base basket modules with a maximum of 12 per package. Intermediate fuel basket modules may contain only intact TRIGA fuel elements.

Maximum decay heat not to exceed 7.5 watts per TRIGA fuel element (or equivalent for damaged fuel) and 900 watts per package. Fuel may not be loaded in the center cell of the non-poisoned TRIGA fuel basket. The cask and baskets must be configured as shown in NAC International Drawing Nos. 315-40-070, 315-40-071, and 315-40-072, and 315-40-079.

5.(b)(2) Maximum quantity of material per package (continued)

(vii)(c) For General Atomics TRIGA fuel elements as described in Item 5.(b)(1)(vi)(c):

Up to 120 intact fuel elements in the TRIGA fuel package with non-poisoned basket. Up to four fuel elements per basket cell only loaded in the six periphery cells. TRIGA fuel elements or sealed cans may not be loaded in the center cell of the non-poisoned basket. Damaged TRIGA fuel elements or fuel debris (up to two equivalent elements of maximum 1.5 inch diameter) shall be transported in a sealed damaged fuel can (one damaged fuel can per cell). The sealed cans are to be in accordance with NAC International Drawing Nos. 315-40-086, 315-40-087, and 315-40-088.

Loading of TRIGA HEU and LEU fuel elements having >138 g and >169 g initial $^{235}U$ mass contents, respectively, are limited to top and bottom basket modules and up to three rods per basket cell. A minimum of one TRIGA dummy rod per NAC Drawing No. 315-40-085 shall be installed in place of a TRIGA fuel element to limit the maximum number of rods per cell to three.

Mixed loading in separate cells of TRIGA fuel elements and TRIGA fuel cluster rods [per 5.(b)(1)(vii)(b)] is authorized in fuel basket modules with the content quantities limited in accordance with the other conditions and limitations of 5.(b)(2)(vii)(c) and 5.(b)(2)(viii)(b).

Maximum decay heat not to exceed 7.5 watts per TRIGA fuel element (or equivalent for damaged fuel) and 900 watts per package. Fuel may not be loaded in the center cell of the non-poisoned TRIGA fuel basket. The cask and baskets must be configured as shown in NAC International Drawing No. 315-40-079.

5.(b)(2) Maximum quantity of material per package (continued)

(viii)(a) For TRIGA fuel cluster rods as described in Item 5.(b)(1)(vii)(a):

Maximum decay heat not to exceed 1.875 watts per TRIGA fuel cluster rod (or equivalent for failed fuel) and 1050 watts per package. TRIGA fuel cluster rods must be positioned in either the non-poisoned TRIGA fuel basket or in the poisoned TRIGA fuel basket. Fuel may not be loaded in the center cell of the non-poisoned TRIGA fuel basket. The non-poisoned basket must be configured as shown in NAC International Drawing Nos. 315-40-070, 315-40-071, and 315-40-072, and the poisoned basket must be configured as shown in NAC International Drawing Nos. 315-40-080, 315-40-081, and 315-40-082.

Up to 480 intact cluster rods per package in the non-poisoned TRIGA fuel baskets (up to six periphery cells loaded with 16 cluster rods each), and up to 560 intact cluster rods per package in the poisoned TRIGA fuel baskets (up to 7 total cells loaded with 16 cluster rods each). TRIGA fuel cluster rods must be positioned within the fuel rod inserts as shown on NAC International Drawing No. 315-40-096.

Damaged TRIGA fuel cluster rods or cluster rod debris (up to six equivalent rods) shall be transported in a sealed damaged fuel can. The sealed cans are to be in accordance with NAC International Drawing Nos. 315-40-086, 315-40-087, and 315-40-088.

Mixed intact and damaged fuel contents and fuel debris are authorized. Base and top fuel basket modules may contain intact fuel cluster rods or sealed DFCs. Intermediate fuel basket modules may contain only intact fuel cluster rods.

(viii)(b) For TRIGA fuel cluster rods as described in Item 5.(b)(1)(vii)(b):

Maximum decay heat not to exceed 1.875 watts per TRIGA fuel cluster rod (or equivalent for failed fuel) and 1050 watts per package. TRIGA fuel cluster rods must be positioned in the non-poisoned TRIGA fuel basket. Fuel may not be loaded in the center cell of the non-poisoned TRIGA fuel basket. The non-poisoned basket must be configured as shown in NAC International Drawing Nos. 315-40-070, 315-40-071, and 315-40-072.

Up to 480 intact cluster rods per package in the non-poisoned TRIGA fuel baskets (up to six periphery cells loaded with 16 cluster rods each), and up to 560 intact cluster rods per package in the poisoned TRIGA fuel baskets (up to 7 total cells loaded with 16 cluster rods each). TRIGA fuel cluster rods must be positioned within the fuel rod inserts as shown on NAC International Drawing No. 315-40-096.

Damaged TRIGA fuel cluster rods or cluster rod debris (up to six equivalent rods) shall be transported in a sealed damaged fuel can. The sealed cans are to be in accordance with NAC International Drawing Nos. 315-40-086, 315-40-087, and 315-40-088.

Mixed intact and damaged fuel contents and fuel debris are authorized. Base and top fuel basket modules may contain intact fuel cluster rods or sealed DFCs. Intermediate fuel basket modules may contain only intact fuel cluster rods.

5.(b)(2) Maximum quantity of material per package (continued)

Mixed loading in separate cells of TRIGA fuel elements [per 5.(b)(1)(vi)(c)] and TRIGA fuel cluster rods [per 5.(b)(1)(vii)(b)] is authorized in fuel basket modules with the content quantities limited in accordance with the other conditions and limitations of 5.(b)(2)(vii)(c) and 5.(b)(2)(viii)(b).

(ix) For high burnup PWR fuel rods, as described in Item 5.(b)(1)(viii): up to 25 fuel rods. Maximum decay heat not to exceed 2.3 kilowatts per package.

Intact individual rods may be placed either in an irradiated or unirradiated fuel assembly lattice (skeleton) or in a fuel rod insert. The PWR fuel assembly lattice must be transported in the PWR basket.

Up to 14 of the 25 fuel rods may be classified as damaged. Damaged fuel rods may include fuel debris, particles, loose pellets, and fragmented rods. Damaged fuel rods must be placed in a fuel rod insert. Damaged fuel rods may also be placed in individual failed fuel rod capsules, as shown in Figure 1.2.3-11 of the application, prior to placement in the fuel rod insert. Guide/instrument tubes and tube segments may be placed in the fuel rod insert. The fuel rod insert must be transported in a PWR/BWR transport canister, which is positioned in the PWR insert in the PWR basket.

(x) For high burnup BWR fuel rods, as described in Item 5.(b)(1)(ix): up to 25 fuel rods. Maximum decay heat not to exceed 2.1 kilowatts per package.

Intact individual rods may be placed either in a fuel assembly lattice or in a fuel rod insert. The BWR fuel assembly lattice must be transported in the PWR insert in the PWR basket.

Up to 14 of the 25 fuel rods may be classified as damaged. Damaged fuel rods may include fuel debris, particles, loose pellets, and fragmented rods. Damaged fuel rods must be placed in a fuel rod insert. Damaged fuel rods may also be placed in individual failed fuel rod capsules, as shown in Figure 1.2.3-11 of the application, prior to placement in the fuel rod insert. Water rods and inert rods may be placed in the fuel rod insert. The fuel rod insert must be transported in a PWR/BWR transport canister, which is positioned in the PWR insert in the PWR basket.

(xi) For DIDO fuel as described in Item 5.(b)(1)(x):

(a) Up to 42 DIDO fuel elements with a maximum decay heat not to exceed 25 watts per DIDO fuel element, provided the top basket fuel element active fuel region is spaced a minimum 3.7 inches from the bottom of the cask lid. Spacing of the active fuel may be accomplished by fuel element hardware, lid spacer, or a combination thereof. Maximum decay heat is 1.05 kilowatts per package. At a top basket active fuel region to cask lid spacing of less than 3.7 inches, the maximum decay heat not to exceed 18 watts per DIDO fuel element and a total of 756 watts per package. The DIDO fuel elements are to be loaded into a DIDO basket configured as shown in NAC International Drawing No. 315-40-111.

5.(b)(2) Maximum quantity of material per package (continued)

(b) A mixed fuel load of up to 42 DIDO fuel elements and spiral and MOATA fuel assemblies [per item 5.(b)(1)(xiv)] in an ANSTO-DIDO combination basket configured as shown in NAC International Drawing No. 315-40-148 consisting of a top ANSTO basket module per NAC International Drawing No. 315-40-140; four intermediate DIDO basket modules per NAC International Drawing No. 315-40-109; and one bottom DIDO basket module per NAC International Drawing No. 315-40-110. DIDO fuel elements loaded into intermediate and bottom basket modules are limited to ≤18 Watts. Up to seven degraded clad DIDO, spiral, and/or MOATA fuel assemblies in DFCs per Figure 1.2.3-18 of the application, or intact DIDO, spiral, and/or MOATA assemblies may be loaded in the top ANSTO module. The per element or DFC heat load limits for the top ANSTO module are: DIDO fuel element with or without DFC is 10 Watts; spiral fuel element in DFC is 10 Watts and 15.7W without DFC; and MOATA fuel element in DFC is 1 Watt and 3 Watts without DFC. Maximum heat load per package is 753 Watts.

(xii) For GA IFM as described in Item 5.(b)(1)(xi):

(a) Mixture of fuel particles (kernels and coatings), fuel compacts (rods), and fuel pebbles, packaged in its own Fuel Handling Unit (FHU).

GA HTGR FHU consists of two redundant canisters. GA HTGR IFM is packaged inside a primary canister with welded closure, as shown in General Atomics Drawing No. 032237, Rev. B, “HTGR Primary Enclosure.” The primary canister is packaged inside a secondary canister with welded closure, as shown in General Atomics Drawing No. 032231, Rev. A, “HTGR Secondary Enclosure.”

GA HTGR FHU total maximum decay heat not to exceed 2.05 watts, and maximum loaded weight not to exceed 71.5 lbs.

(b) Twenty irradiated TRIGA fuel elements; 13 of the elements are intact, and the remaining 7 are sectioned. GA RERTR IFM is packaged in its own FHU.

GA RERTR FHU consists of two redundant canisters. GA RERTR IFM is packaged inside a primary canister with welded closure, as shown in General Atomics Drawing No. 032236, Rev. B, “RERTR Primary Enclosure.” The GA RERTR IFM primary canister is packaged inside a secondary canister with welded closure, as shown in General Atomics Drawing No. 032230, Rev. A, “RERTR Secondary Enclosure.”

GA RERTR FHU total maximum decay heat not to exceed 11 watts, and maximum loaded weight not to exceed 76.0 lbs.

5.(b)(2) Maximum quantity of material per package (continued)

(xiii) For TPBARs as described in Item 5.(b)(1)(xii):

Up to 300 TPBARs, including a maximum of 2 damaged rods, positioned within a consolidation canister, as shown in Figure 1.2.3-10 of the application. The consolidation canister is transported in a TPBAR basket assembly. The maximum decay heat is 2.31 watts per rod and 693 watts per package. The maximum weight of the TPBARs and the consolidation canister is 1,000 pounds. Consolidation canisters with fewer than 300 TPBARs may also contain stainless steel spacers of various geometries. The total weight and volume of the reduced TPBAR contents plus the spacers must be less than or equal to the weight and volume of 300 TPBARs.

Up to 25 TPBARS, including a maximum of 2 prefailed rods, positioned within a PWR/BWR Rod Transport Canister. The PWR/BWR Rod Transport Canister is transported in a TPBAR basket assembly. The maximum decay heat is 2.31 watts per rod and 58 watts per package.

(xiv) For PULSTAR fuel as described in Item 5.(b)(1)(xiii):

Up to 700 intact or damaged PULSTAR fuel elements in either assembly or element form, including fuel debris, pellets, pieces and nonfuel components of PULSTAR fuel assemblies. The contents of a PULSTAR can are restricted to the equivalent of the fuel material in 25 intact PULSTAR fuel elements and of the displaced volume of 25 intact PULSTAR fuel elements.

(xv) For ANSTO fuel as described in Item 5.(b)(1)(xiv):

(a) Up to 42 spiral fuel assemblies, MOATA plate bundles, or any combination of spiral fuel assemblies and MOATA plate bundles. ANSTO fuel must be loaded within ANSTO basket modules. Spiral fuel assemblies may be cropped by removing nonfuel-bearing hardware to fit the ANSTO basket modules. Fuel assemblies that are cropped, but are otherwise intact, may be considered intact. For spiral fuel

5.(b)(2) Maximum quantity of material per package (continued)

(a) (continued) assemblies, the maximum decay heat per assembly is 15.7 watts. The minimum cool time as a function of burnup shall be consistent with the maximum decay heat limit and shall be determined using the procedures for medium enriched DIDO fuel in Section 7.1.4 of the application; the minimum cool time may not be less than 270 days. For MOATA plate bundles, the maximum heat load per bundle is 3 watts, and the minimum cool time is 10 years.

(b) A mixed fuel load of up to 42 spiral and MOATA fuel assemblies and DIDO fuel elements [per item 5.(b)(1)(x)] in an ANSTO basket configured as shown in NAC International Drawing No. 315-40-139. Degraded clad elements placed in DFCs per Figure 1.2.3-18 of the application or intact DIDO fuel elements are limited to loading in the top ANSTO basket module. Maximum heat load per DIDO element is 10W. Degraded clad spiral and MOATA fuel assemblies in DFCs are also limited to loading in the top ANSTO basket module. Spiral fuel assemblies placed into DFCs are limited to a maximum of 10W and MOATA plate bundles loaded in DFCs are limited to 1W. Spiral fuel elements not placed in DFCs are limited to 15.7W and MOATA plate bundles not placed in DFCs are limited to a maximum of 3W with a minimum cool time of 10 years.

(xvi) For segmented TPBARs as described in Item 5.(b)(1)(xv):

Up to 55 equivalent TPBARs as segments and segmentation debris, placed within a welded waste container, as shown in Figure 1.2.3-16 of the application. The waste container is transported in a TPBAR basket assembly. The maximum decay heat is 2.31 watts per equivalent TPBAR and 127 watts per package. The maximum weight of the segmented TPBARs and the TPBAR waste container is 700 pounds.

(xvii) For solid irradiated hardware as described in Item 5.(b)(1)(xvi):

Up to 4,000 pounds, including spacers, dunnage and containers, and meeting the gamma source defined in Table 1.2-13 of the application. An irradiated hardware spacer source, per NAC Drawing No. 315-40-145, shall be installed.

(xviii) For intact PWR MOX fuel rods as described in Item 5.(b)(1)(xvii):

Up to 16 undamaged irradiated PWR MOX rods or a combination of PWR MOX and high burnup PWR fuel rods as described in Item 5.(b)(1)(viii). Maximum decay heat not to exceed 2.3 kW per package. Individual PWR MOX and PWR $UO_2$ fuel rods shall be placed in a 5x5 insert loaded into a screened or free flow rod canister in accordance with NAC International Drawing No. 315-40-104, for transport. Up to nine nonstainless burnable poison rods (BPRs) may be loaded in the spare locations in the 5x5 insert. The PWR/BWR fuel rod canister shall be transported in the PWR basket and the PWR insert installed in the cask cavity.

5(c) Criticality Safety Index (CSI)

| | |
|---|---|
| For PWR fuel assemblies described in 5(b)(1)(i) and limited in 5(b)(2)(i) | 100 |
| For BWR fuel assemblies described in 5(b)(1)(ii) and limited in 5(b)(2)(ii) | 5.0 |
| For MTR fuel elements described in 5(b)(1)(iv) and limited in 5(b)(2)(iv) | 0.0 |
| For metallic fuel rods described in 5(b)(1)(v) and limited in 5(b)(2)(v) and (vi) | 0.0 |
| For TRIGA fuel elements (in poisoned TRIGA fuel baskets) described in 5(b)(1)(vi)(a) and limited in 5(b)(2)(vii)(a) | 0.0 |
| For TRIGA fuel elements (in nonpoisoned TRIGA fuel baskets) described in 5(b)(1)(vi)(b) and 5(b)(1)(vi)(c) and limited in 5(b)(2)(vii)(b) and 5(b)(2)(vii)(c), respectively | 12.5 |
| For mixed loads of TRIGA fuel elements described in 5(b)(1)(vi)(c) and limited in 5(b)(2)(vii)(c), and TRIGA fuel cluster rods described in 5(b)(1)(vii)(b) and limited in 5(b)(2)(viii)(b) | 12.5 |
| For TRIGA fuel cluster rods described in 5(b)(1)(vii) and limited in 5(b)(2)(viii) | 0.0 |
| For high burnup PWR rods described in 5(b)(1)(viii) and limited in 5(b)(2)(ix) | 0.0 |
| For high burnup BWR rods described in 5(b)(1)(ix) and limited in 5(b)(2)(x) | 0.0 |
| For DIDO fuel elements described in 5(b)(1)(x) and limited in 5(b)(2)(xi) | 12.5 |
| For General Atomic Irradiated Fuel Material (GA IFM) described in 5(b)(1)(xi) and limited in 5(b)(2)(xii) | 0.0 |
| For TPBARS and segmented TPBARS described in 5(b)(1)(xii) and 5(b)(1)(xv) and limited in 5(b)(2)(xiii) and 5(b)(2)(xvi) | 0.0 |

5(c) Criticality Safety Index (CSI)

| | |
|---|---|
| For intact (uncanned) PULSTAR fuel described in 5(b)(1)(xiii) and limited in 5(b)(2)(xiv) | 0.0 |
| For (canned) PULSTAR fuel described in 5(b)(1)(xiii) and limited in 5(b)(2)(xiv) – for a package with any number of PULSTAR cans | 33.4 |
| For ANSTO fuel described in 5(b)(1)(xiv) and limited in 5(b)(2)(xv) | 0.0 |
| For solid irradiated hardware described in 5(b)(1)(xvi) and limited in 5(b)(2)(xvii) | 0.0 |
| For PWR MOX rods described in 5.(b)(1)(xvii) and limited by 5(b)(2)(xviii) | 0.0 |
| For a mixed fuel load of DIDO and ANSTO fuel elements described in 5(b)(1)(x) and 5(b)(1)(xiv) and limited by 5(b)(2)(xi)(b) and 5(b)(2)(xv)(b) | 0.0 |

6. Known or suspected damaged fuel assemblies (rods) or elements, and fuel with cladding defects greater than pin holes and hairline cracks are not authorized, except as described in Items 5.(b)(1)(x); 5.(b)(1)(xiv); 5.(b)(2)(iv)(d); 5.(b)(2)(vi); 5.(b)(2)(vii)(a); 5.(b)(2)(vii)(b); 5.(b)(2)(viii); 5.(b)(2)(ix); 5.(b)(2)(x); 5.(b)(2)(xi); 5.(b)(2)(xiv); and 5.(b)(2)(xv).

7. The cask must be dry (no free water) when delivered to a carrier for transport.

8. Bolt torque: The cask lids bolts must be torqued to 260 +/- 20 ft-lbs. The bolts used to secure the alternate vent and drain port covers must be torqued to 100 +/- 10 inch-lbs. The bolts used to secure the Alternate B port covers must be torqued to 285 +/- 15 inch-lbs.

9. Prior to each shipment, the package must be leak tested to 1 x $10^{-3}$ std $cm^3$/sec, except that replaced seals must be leak tested to 2.0 x $10^{-7}$ std $cm^3$/sec (He). Prior to first use, and at least once within the 12-month period prior to each subsequent use, the package must be leak tested to 2.0 x $10^{-7}$ std $cm^3$/sec (He).

10. In addition to the requirements of Subpart G of 10 CFR Part 71:

(a) The metallic O-ring lid seal must be replaced prior to each shipment; and

(b) Each package must meet the Acceptance Tests and Maintenance Program of Chapter 8 of the application; and

10. (continued)

(c) The package shall be prepared for shipment and operated in accordance with the Package Operations of Chapter 7 of the application. If the cask is loaded under water or water is introduced into the cask cavity, the cask must be vacuum dried as described in Chapter 7 of the application. The cask cavity must be backfilled with 1.0 atm of helium when shipping PWR or BWR assemblies, individual PWR and BWR rods, or TPBAR contents.

11. When shipping PWR, BWR, PWR MOX, MTR, DIDO assemblies, TRIGA fuel elements, TRIGA fuel cluster rods, high burnup PWR or BWR rods, GA IFM, PULSTAR fuel elements, spiral fuel assemblies, and MOATA plate bundles, the neutron shield tank must be filled with a mixture of water and ethylene glycol which will not freeze or precipitate in a temperature range from -40 °F to 250 °F. The water and ethylene glycol mixture must contain at least 1% boron by weight.

12. A personnel barrier must be used when shipping PWR or BWR assemblies. Shipments of MTR, DIDO fuel assemblies, TRIGA fuel elements, TRIGA fuel cluster rods, high burnup PWR or BWR rods, PWR MOX rods, TPBAR contents, PULSTAR fuel elements, spiral fuel assemblies, MOATA plate bundles, or irradiated hardware must use the ISO container or a personnel barrier.

13. Packages used to ship metallic fuel rods may be shipped in a closed shipping container provided that the closed container, the cask tie-down and support system and transport vehicle (trailer) meet the applicable requirements of the Department of Transportation. When the cask is shipped in a closed shipping container, the center of gravity of the combined cask, closed shipping container and trailer must not exceed 75 inches.

14. For shipment of TPBAR contents:

(a) Prior to first use for shipment of TPBAR contents, each packaging must be hydrostatic pressure tested to 450 +15/-0 psig, as described in Section 8.1.2 of the application;

(b) The package must be marked with Package Identification Number USA/9225/B(M)-96;

(c) The package must be configured as shown in NAC International Drawing No. 315-40-128, Rev. 3, for the applicable TPBAR contents; and

(d) Prior to each shipment, after loading, each cask containment seal must be tested to show no leakage greater than 2 x $10^{-7}$ std-$cm^3$/s (helium).

15. For shipment of PULSTAR fuel:

(a) Intact fuel elements may be configured as PULSTAR fuel assemblies, may be placed into a TRIGA fuel rod insert (a 4 x 4 rod holder), or may be loaded into PULSTAR fuel cans. Intact PULSTAR fuel assemblies and PULSTAR fuel elements in a TRIGA fuel rod insert may be loaded in any module of the 28 MTR basket assembly. PULSTAR fuel cans may only be loaded into the top or base module of the 28 MTR basket assembly.

15. (continued)

(b) Damaged PULSTAR fuel elements and nonfuel components of PULSTAR fuel assemblies must be loaded into PULSTAR cans. Damaged PULSTAR fuel, including fuel debris, pellets or pieces, may be placed in an encapsulating rod prior to loading into a PULSTAR fuel can. PULSTAR fuel cans may only be loaded into the top or base module of the 28 MTR basket assembly.

(c) Loading of modules with mixed PULSTAR payload configuration is allowed.

16. For shipment of non-fissile contents, with fissile content in the package not exceeding Type A quantity, and qualifying as a fissile exempt quantity under 10 CFR 71.15, the ModelNo. NAC-LWT shall be designated as Type B(U)F-96, with package identification number USA/9225/B(U)-96.

17. Transport by air is not authorized.

18. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

19. Revision 53 of this certificate may be used until March 31, 2011.

20. Expiration Date: February 28, 2015.

## REFERENCES

NAC International, Inc., application dated January 22, 2010.

NAC International, Inc., supplements dated February 9 and 23 and March 3, 2010.

FOR THE U. S. NUCLEAR REGULATORY COMMISSION

[signature]

Eric J. Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Date: March 23, 2010

SAFETY EVALUATION REPORT

Docket No. 71-9225
Model No. NAC-LWT Package
Certificate of Compliance No. 9225
Revision No. 55

## SUMMARY

By application dated February 9, 2010, as supplemented February 23 and March 3, 2010, NAC International (NAC or the applicant), requested a revision of Certificate of Compliance (CoC) No. 9225, for the Model No. NAC-LWT package. NAC requested changes to the authorized TRIGA fuel contents.

On March 4, 2010, the U.S. Nuclear Regulatory Commission, issued Revision 54 to CoC No. 9225 for the Model No. NAC-LWT package. After issuing Revision 54 of the CoC No. 9225, several typographical errors were identified in the CoC. The errors have been corrected as delineated below. Changes made to the enclosed CoC are indicated by vertical lines in the margin.

## CONDITIONS

Condition No. 5.(a)(3)(ii) was revised to fix a typographical error. The word "Bottom" was deleted in the title of LWT 315-40-110, Rev. 1.

Condition No. 5.(b)(1)(vi)(c) was revised to fix a typographical error. Footnotes 7 and 8 to the table were revised to clarify "basket modules" and basket module cells."

Condition No. 5.(b)(2)(vii)(c) was revised to correct "<169 g" to read ">169 g."

The supplement dated March 3, 2010 was added to the references.

## CONCLUSION

These changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9225, Revision No. 55, on <u>March 23, 2010</u>.

U.S. Department
of Transportation

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Washington, D.C. 20590

Pipeline and
Hazardous Materials
Safety Administration

**CERTIFICATE NUMBER:** USA/9225/B(U)F-96, Revision 48

**ORIGINAL REGISTRANT(S):**

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