June 28, 2007

James M. Shuler
Manager, Packaging Certification Program
Safety Management and Operations
Office of Environmental Management
Department of Energy
Washington, DC 20585

SUBJECT: REVISION 4 OF CERTIFICATE OF COMPLIANCE NO. 9315 FOR THE MODEL NO. ES-3100

Dear Dr. Shuler:

As requested by your letter dated January 31, 2007, as supplemented February 22, April 11, May 30, and June 27, 2007, enclosed is Certificate of Compliance No. 9315, Revision No. 4, for the Model No. ES-3100 package. You requested the addition of unirradiated TRIGA fuel, including air transport, for this shipping container. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's Safety Evaluation Report is also enclosed.

Those on the attached list have been registered as users of the package under the general license provisions of 10 CFR 71.17 or 49 CFR 173.471. This approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471. Registered users may request, by letter, to remove their names from the Registered Users List.

If you have any questions regarding this certificate, please contact me or Kim Hardin of my staff at (301) 492-3294.

Sincerely,

/RA/

Robert A. Nelson, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9315
TAC No. L24057

Enclosures:
1. Certificate of Compliance No. 9315, Rev. No. 4
2. Safety Evaluation Report
3. Registered Users List

cc w/encls 1 & 2: R. Boyle, Department of Transportation
Registered Users
J. Arbital, BWXT Y-12

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SAFETY EVALUATION REPORT
Docket No. 71-9315
Model No. ES-3100 Package
Certificate of Compliance No. 9315
Revision No. 4

SUMMARY

By application dated January 31, 2007, as supplemented February 22, April 11, May 30, and June 27, 2007, the Department of Energy (DOE or the applicant) requested amendment No. 4 to Certificate of Compliance (CoC) No. 9315, for the Model No. ES-3100 package. This revision incorporates as approved contents unirradiated Training, Research, Isotopes, and General Atomics (TRIGA) reactor fuel, including air transport, and will support safe shipments to support the DOE NNSA Foreign Research Reactor (FRR) Program.

The submittal was evaluated against the regulatory standards in 10 CFR Part 71, including the general standards for all packages, standards for fissile material packages, and performance standards under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). Staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

Based on the statements and representations in the application, as supplemented, and the conditions listed in the CoC, the staff concludes that the design has been adequately described and evaluated and meets the requirements of 10 CFR Part 71.

GENERAL INFORMATION

By application dated January 31, 2007, as supplemented, DOE requested the additional authorized contents of unirradiated TRIGA fuel in the form of uranium zirconium hydride, including air transport. No other changes were made to the package design. Other clarification type changes to the CoC were also made.

The request includes authorization to ship fuel pellets (sections) from dismantled unirradiated TRIGA fuel of three types: standard fuel elements, instrumented standard fuel elements, and fuel follower control rods. The fuel elements will be dismantled and the sections placed into convenience cans. The air shipments authorized were requested with no 10 CFR 71.55(f) physical testing provided. For this reason, a very low fissile mass is allowed per package. No credit was taken in the criticality safety analysis for the structural integrity of the package or its contents under air transport HAC.

STRUCTURAL AND MATERIALS EVALUATION

The staff reviewed the application to revise the Model No. ES-3100 package to assess whether the package will remain within the allowable values or criteria for NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 2 (Structural Review) of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

All the structural and materials review associated with the construction and materials of the package and contents of the package conducted in the original review are still valid and have not been reviewed further.

Since the TRIGA fuel is unirradiated and generates no gas, the only sections of the Safety Analysis Report (SAR) with materials implications for these changes are Sections 1 and 6. Since changes in Section 1 were specifically delineated only those changes were reviewed. Since, as indicated on page 6.1 of the SAR, Section 6 was completely revised, all parts of Section 6 related to these requested changes were reviewed.

The maximum quantity of the TRIGA fuel to be shipped is limited to a subcritical quantity when no credit is taken for the configuration of the fuel. Therefore, mechanical properties of the fuel and cladding were not required. Since it is unirradiated, the fuel generates no gamma field for the unshielded package, nor does it produce any heat; therefore, there is no affect on the materials previously approved for this package. The UZrH is stable in the shipping environment since pyrophoric uranium hydride does not form. Uranium hydrides have not been observed in photomicrographs of TRIGA fuel.

The provisions of 10 CFR 71.55(f) require Fissile material packages transported by air to maintain subcriticality under a number of prescribed tests. The criticality analysis for air transportation does not credit the package for maintaining the geometric configuration of its contents or packaging. Therefore, staff agrees that the material and structural aspects related to this revision are adequate.

Based on the statements and representations in the application, as supplemented, and the conditions listed in the CoC, the staff concludes that the design has been adequately described and evaluated and meets the structural and material requirements of 10 CFR Part 71.

CRITICALITY SAFETY EVALUATION

The applicant revised the criticality safety evaluation in the Safety Analysis Report (SAR) for the Model No. ES-3100 package to consider unirradiated TRIGA reactor elements as authorized contents. The staff reviewed the application to revise the Model No. ES-3100 package to verify that the package criticality design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 6 (Criticality Review) of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

The revised contents consist of unirradiated TRIGA fuel pellets (sections). The fuel is composed of uranium zirconium hydride (UZrH). The uranium concentration in the fuel is a nominal 8.5 weight percent, and the maximum H to Zr ratio in the fuel is 2.0. The maximum uranium enrichment is 70 weight percent ^{235}U. The fuel sections may be from any of three types of fuel elements: standard fuel elements, instrumented standard fuel elements, and fuel follower control rods. The ^{235}U mass for the standard and instrumented fuel elements is a nominal 136 grams per element, and the ^{235}U mass for fuel follower control rods is a nominal 112 grams per element. Each element contains three fuel sections, which are removed from the cladding for transport. The fuel sections are approximately 5 inches in length; the approximate diameter is 1.44 inches for the standard and instrumented fuel elements, and 1.31 inches for the fuel follower control rods. The fuel sections are packaged within stainless steel or tin-plated carbon steel convenience cans, with a maximum of three fuel sections per

convenience can. Fuel sections from different fuel elements may not be mixed within a single convenience can. A maximum of three convenience cans may be loaded into a single package.

The applicant's revised criticality analysis considers single packages per the requirements of 10 CFR 71.55 and arrays of packages per the requirements of 10 CFR 71.59. The analysis also considers special requirements for fissile material package designs to be transported by air contained in 10 CFR 71.55(f).

For the evaluation of a single package under both NCT and HAC, the applicant considered both intact fuel and severely damaged fuel within the containment vessel of the package, since the structural integrity of the fuel during NCT and HAC cannot be determined from the testing performed. The applicant evaluated TRIGA fuel enriched to 19.7 wt% ^{235}U, in addition to 70 wt%. Analyses presented in Section 6.4 of the SAR demonstrate that the 19.7 wt% enriched TRIGA fuel is more reactive than the 70 wt% enriched, due to the fact that there is more than twice the amount of ^{235}U in the lower enriched fuel (i.e., 921 grams ^{235}U in the 19.7 wt% fuel element vs. 408 grams ^{235}U for the 70 wt% fuel element).

For the intact fuel, the applicant modeled the fuel sections stacked end to end in the containment vessel, neglecting any spacing that would be provided by the convenience cans. The three resulting fuel cylinders were modeled with a pitch varying within the radial boundary of the convenience cans. The applicant also modeled the package fully reflected with water and with varying moderator density (0 - 100%) inside the containment vessel. For reconfigured fuel, the applicant modeled the UZrH material homogeneously dispersed within varying moderator density over the free volume of the containment vessel. The maximum $k_{eff} + 2\sigma$ determined for the single package is 0.611.

For the evaluation of package arrays under both NCT and HAC, the applicant modeled infinite arrays of packages, containing the maximum loading of 19.7 wt% enriched intact fuel sections, with varying internal and interstitial moderator density. The most reactive condition was determined to be with maximum moderation inside the containment vessel, with no additional water outside the vessel. This situation results in the most neutron communication between packages in the array. The maximum $k_{eff} + 2\sigma$ determined for arrays of packages with intact fuel sections is 0.526. The applicant provided evaluations for the TRIGA fuel as damaged under NCT and HAC, as was done for the single package analysis. The maximum $k_{eff} + 2\sigma$ for these evaluations is 0.716. Since infinite arrays of packages were shown to be subcritical under NCT and HAC, the resulting criticality safety index (CSI) for the package with the contents described above is 0.0.

For the evaluation of the catastrophically damaged package under air transport, the applicant did not credit any structural properties of the package or its contents, since no testing was performed to demonstrate that either would remain intact under the conditions of 10 CFR 71.55(f). Instead the applicant assumed that the various materials of the package would either be removed from, provide a reflector for, or become homogeneously mixed with the fissile material in a worst case (spherical) geometry. Various models are proposed in Section 6.3.1.4 of the SAR, the most reactive of which is Model 5, where the fissile material is surrounded by water saturated kaolite and the water may become mixed in the core to a varying density. This model resulted in a k_{eff} greater than the applicant's calculated upper subcritical limit (USL) for the 19.7 wt% enriched material. The applicant performed additional analyses for the 70 wt% enriched material, which resulted in a maximum $k_{eff} + 2\sigma$ of 0.82415 (Table 6.9.6-22b of the SAR). This revision only authorizes the 70 wt% enriched material whose $k_{eff} + 2\sigma$ is well below the USL of 0.925.

The applicant used the CSAS25 control module of SCALE 4.4a with the 238-group ENDF/B-V cross-section library for all calculations. The applicant provided an overview of the bias determination methodology used to benchmark this code and cross-section library for generalized uranium systems. This methodology is based on k_{eff} determinations of critical systems from the Nuclear Energy Agency's International Handbook of Evaluated Criticality Safety Benchmark Experiments. Although the applicant did not provide the details of the bias determination specifically for the TRIGA fuel material to be transported (a generalized benchmarking analysis is provided in BWXT-Y12 document Y/DD-896/R1, "Critical Experiment Benchmark Calculations with CSAS25 from SCALE 4.4a for Criticality Safety Analyses on the J-5600 Unclassified Workstation (CMODB)"), the reported upper subcritical limit (USL) of 0.925 is accepted by the staff due to: the relatively conservative value determined for the USL based on previous experience; and the large margin between k_{eff} and the USL for all of the most reactive situations. Future amendments that reduce this margin or increase the USL will require more detail in the benchmarking analysis.

The staff performed confirmatory calculations using the SCALE 5.1 code system with KENO V.a and the 238 group ENDF/B-V cross section library, with modeling assumptions similar to the applicant's. The staff modeled the single package air-transport configuration as a sphere of 70 wt% enriched $UZrH_2$ fuel homogeneously mixed with varying density water and reflected by 30 cm of full density water. The resulting k_{eff}'s were similar to those calculated by the applicant. The staff also modeled an infinite array of packages containing damaged fuel sections. The fuel was assumed to homogeneously mix with varying density water within the containment vessel. No water was assumed outside of the containment vessel or in between packages in the array, in order to create the maximum neutron communication between fissile units. The most reactive model produced a k_{eff} consistent with the results of the applicant's damaged fuel infinite array model.

All of the resulting maximum k_{eff}'s for the contents requested calculated by the applicant are below the reported USL. The applicant has shown and the staff agrees that the Model No. ES-3100 package meets the criticality safety requirements for fissile material single packages under 10 CFR 71.55, for air transport of fissile material packages under 10 CFR 71.55(f), and for arrays of packages under 10 CFR 71.59, when limited to 3 unirradiated TRIGA fuel elements, as described above, enriched to 70 wt% ^{235}U with 408 g ^{235}U.

CONDITIONS

The CoC has been revised as follows:

Condition No. 5.(b)(2):

> Revised to clarify that the maximum uranium enrichment is 100 weight percent U-235 and to specify that no carbide compounds are authorized.

Condition No. 5.(b)(3):

> Revised to clarify that the maximum uranium enrichment is 100 weight percent U-235.

Condition No. 5.(b)(4):

> Specifies the addition of the authorized TRIGA fuel.

Condition No. 11:

Specifies the air transport contents.

Condition No. 14:

Allows the use of Revision 3 of this certificate for one year.

CONCLUSION

The Certificate of Compliance is revised to authorized shipments of TRIGA reactor fuel sections, including air transport, and various clarification changes.

This change does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9315, Revision No. 4 on June 28, 2007.