SAFETY EVALAUTION REPORT
Model No. TN-BGC1 Package
French Certificate of Approval No. F/313/B(U)F-96
Docket No. 71-3034

SUMMARY

By letter dated December 5, 2007, the U.S. Department of Transportation (DOT) requested that the Nuclear Regulatory Commission (NRC) review the Model No. TN-BGC1 package, authorized by French Certificate of Approval No. F/313/B(U)F-96, Rev. No. Hag. DOT requested that the NRC provide a recommendation concerning revalidation of the certificate for import and export use via air transport. DOT also requested that the review be limited to the criticality assessment for air transport of Content No. 11 (solid non-irradiated uranium-bearing materials contained within a TN-90 secondary conditioning container) and Content No. 26 (non-irradiated TRIGA fuel elements). DOT provided the following documents: (1) Commisariat A L'Energie Atomique Document No. DEN/DTAP/SPI/GET entitled "Chapter 9 – Appendix 7, Criticality Safety of the TN-BGC1 Package Design Loaded with Content 11 for Air Transport," dated July 8, 2003; and (2) Framatome ANP Document No. FF/NH/DC/0098, entitled "Criticality Safety Study of TN BGC1 Cask Transport of TRIGA Elements," Revision D. Supplemental information was provided on December 12, 20, and 21, 2007.

Based upon our review, the statements and representations in the documents described above, and for the reasons stated in this safety evaluation report, we agree that the TN-BGC1 package, as described in French Certificate of Approval No. F/313/B(U)F-96, Rev. Hag, meets the requirements of paragraph 680 of International Atomic Energy Agency (IAEA) "Regulations for the Safe Transport of Radioactive Material," TS-R-1, 1996 Edition (Revised), for Content No. 11 and Content No. 26, as limited in U.S. Department of Transportation Competent Authority Certificate USA/0492/B(U)F-96, Revision 9, with the following additional conditions:

1. For Content No. 11, the maximum fissile mass not to exceed 5 kilograms U-235 per package. The mass of water must not exceed 2000 grams per package in the form of moisture content of wood. No hydrogenous packaging materials are permitted within the package containment vessel.
2. For Content No. 26, the maximum number of TRIGA fuel elements per package not to exceed 5 standard elements or 23 thin elements, where standard and thin elements are defined in F/313/B(U)F-96 26ag, Appendix 26, Content No. 26. The total mass of cardboard must not exceed 1200 grams, the moisture content of the wood components must not exceed 10 percent, and the total water content (including moisture content of the wood and water equivalent in the form of cardboard) must not exceed 2900 grams per package. No other hydrogenous packaging materials are permitted within the package containment vessel.

EVALUATION

By way of background, the TN-BGC1 package design was previously reviewed by NRC. The review was based on the IAEA Safety Series 6, 1985 Edition (As Amended 1990), which were the regulations in effect at the time. The staff limited its review to Content No. 11, uranium in any solid form, excluding metallic powder, within the TN 90 secondary container. In NRC letter dated July 25, 2000, the staff recommended that DOT revalidate the French certificate, limited to those contents. The maximum mass of U-235 per package was limited based on the type of solid spacers used within the package. The current request from DOT is for air transport of Content No. 11, and TRIGA fuel elements (Content No. 26). Based on the request from DOT, the staff considered the ability of the package to meet the requirements of paragraph 680 of TS-R-1 (special requirement for air transport of fissile material).

1. General Information

1.1 Packaging

The packaging consists of an outer rectangular cage constructed of aluminum tubes and an inner cylindrical body constructed of concentric stainless steel shells with a solid resin between the shells. The cage has outer dimensions of approximately 600 mm by 600 mm by 1821 mm in length. It is constructed of an assembly of aluminum tubes (30 mm by 30 mm with a 2-mm wall thickness) that are welded together. The top of the cage is open for removal of the main body. Perforated aluminum plates are incorporated into the cage to act as a personnel barrier.

The main body is composed of a stainless steel containment vessel surrounded by a solid resin thermal shield with a minimum thickness of 48 mm, which is enclosed in a second stainless steel shell. The main body is connected to the outer cage by a series of attachment lugs. The resin acts as a neutron absorber and thermal insulator. The containment vessel shell is 6-mm thick and is welded to an 8-mm thick bottom plate. The outer stainless steel shell is 1.5-mm thick. The bottom end of the body incorporates a wood impact limiter within the outer stainless steel shell. The containment vessel cavity is 178 mm in diameter and 1475-mm long. The cavity is closed by a stainless steel lid that has leak testable, double O-ring seals. The top closure is equipped with a resin and wood top cover (impact limiter) that is attached to the main body.

Contents are loaded and positioned within the containment vessel using a system of secondary containers and spacers. The maximum total weight of the package is approximately 400 kg.

1.2 Drawings

The packaging is shown on the following drawings:

Design and overall arrangement	TN-9990-65 (C)
Cage	TN-9990-118 (B)
Plug assembly	TN-9990-117 (B)

1.3 Contents

The contents are described in French Certificate of Approval No. F/313/B(U)F-96, Rev. No. Hag, as limited in U.S. Department of Transportation Competent Authority Certificate USA/0492/B(U)F-96, Revision 9. The following contents were considered:

- Content No. 11 (solid unirradiated uranium and uranium compounds), and
- Content No. 26 (unirradiated TRIGA fuel elements).

1.4 Criticality Safety Index

The Criticality Safety Index (CSI) for the package, as specified in French Certificate of Approval No. F/313/B(U)F-96, Rev. No. Hag, and U.S. Department of Transportation Competent Authority Certificate USA/0492/B(U)F-96, Revision 9, is as follows:

CSI for Content No. 11	1.0
CSI for Content No. 26	0.0

2. CRITICALITY EVALUTION

For air transport of fissile material, the provisions of paragraph 680 in TS-R-1 apply. Paragraph 680 specifies, in part, that a single package must be subcritical under conditions consistent with the Type C package tests, assuming reflection by at least 20 cm of water but no water inleakage. The applicant assumed that the package cannot survive the Type C tests, and provided a criticality assessment based on the possible reconfiguration of the fissile material and the moderating materials present in the packaging, assuming worst-case effects of the mechanical and thermal tests. This is consistent with guidance in IAEA “Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material,” Safety Guide No. TS-G-1.1.

2.1 Content No. 11 – Uranium and Compounds

Chapter 9 – Appendix 7 “Criticality Safety of the TN-BGC1 Package Design Loaded with Content 11 for Air Transport,” provides the criticality analysis for a single package. The analysis assumes the maximum fissile load of 7 kilograms of uranium, assumed to be 100 percent U-235. The mass of water contained in the packaging (lid and base) is estimated to be less than 2000 grams. This is based on a mass of 17 kilograms of wood used in the packaging, and a moisture content of 10 percent, as provided in the supplement dated December 12, 2007. The mass of water was rounded up to 2000 grams to provide a safety margin. Other packaging materials that were considered in the analysis include stainless steel (which could act as a neutron reflector). Aluminum spacers and inner containers are not considered in the analysis. Credit is not taken for the presence of the borated resin, which acts as a neutron absorber.

The applicant considered five models for the criticality analysis, as described in Section 1.4 of Chapter 9 – Appendix 7. In general, the fissile material is modeled as a sphere, surrounded by concentric spheres. The most reactive cases assumed moderation of the fissile material by 2000 grams of water, with stainless steel closely surrounding the fissile material. The stainless steel thickness was varied to ensure full reflection. Heterogeneous and homogeneous fuel-water mixtures were considered.

The staff performed independent calculations for Content No. 11. As specified by the applicant, a fissile mass of 5 kilograms was assumed. The staff assumed a homogeneous mixture of U-235 and water, with a maximum water content of 2000 grams, consistent with the applicant. A full thickness reflector of stainless steel of 17.80 centimeters (340 kg of stainless steel) surrounded by an additional 20 centimeters of water reflector was modeled. The staff evaluation resulted in a k-eff = 0.87387 ± 0.00080. The overall experiment model uncertainty and bias is approximately ± 0.0015 Δk/k by comparison with the HEU-MET-FAST-013 benchmark experiment of the International Handbook of Evaluated Criticality Safety Benchmark Experiments (Sept. 2007 Edition). The results of staff's calculations confirmed that the maximum k-eff for this case was less than 0.95 considering statistical uncertainties.

The staff agrees with the applicant's conclusion that the package meets the requirements of paragraph 680 of TS-R-1, when limited to a fissile mass of 5 kilograms of U-235 and a packaging moderating material content not greater than an equivalent of 2000 grams water.

2.2 Content No. 26 – TRIGA Fuel

Framatome ANP Document FF/JN/DC/0098, "Criticality Safety Study of TN BGC1 Cask Transport of TRIGA Elements," Rev. D, provides the criticality analyses for the package loaded with TRIGA fuel. The staff reviewed Section 6.5 "Justification for air transport" which provides the criticality assessment against the requirements of paragraph 680 in TS-R-1.

The applicant considered various types of TRIGA fuel elements, including standard (3.63 centimeters in diameter) and thin (1.29 centimeters in diameter) elements. The applicant identified Type 119 and Type 424 elements as the most limiting from a criticality standpoint for the standard and thin element types authorized in the French Certificate, respectively.

The applicant performed a series of calculations using MCNP4B. As with Content No. 11, and consistent with TS-G-1.1, the applicant assumed that the fissile material was in a spherical geometry, surrounded by packaging materials and water reflection. Three configurations were evaluated, as described in Section 6.5.1 "Calculation scenarios." The most reactive configuration included fuel moderated with water (which was varied in mass). The moderated fuel region was assumed to be surrounded by unmoderated fuel, steel, resin, and full water reflection. Calculations were run with and without the steel and resin regions. The most reactive configuration for Type 119 fuel was also repeated for Types 117, 105, and 103 standard elements. The applicant showed that the maximum k-eff, including 3σ statistical uncertainty, did not exceed 0.95.

The staff performed independent calculations for the TRIGA fuel elements. The staff considered the supplementary information provided on December 20 and 21, 2007. The staff performed the analysis assuming 5 TRIGA standard fuel elements or 23 thin fuel elements per package. The staff modeled the TRIGA contents with a moderating mass of water from 2000 to 2900 grams of water, consistent with the applicant's analysis. The staff also increased the water mass to 3500 and 4600 grams, as a sensitivity study. The analysis for 4600 grams represented 20-percent moisture content in the wood packaging components. The staff assumed a wood mass of 17 kilograms, consistent with the applicant. The corresponding water content assumed to be present in the wood was therefore 3400 grams. Cardboard packaging provided an additional 1200 grams of water equivalent (200 grams per piece and 6 pieces of cardboard per package). For the sensitivity study the maximum total water mass assumed was 3400 + 1200 = 4600 grams.

The staff's results confirmed the applicant's. The staff calculated a k-eff of 0.78982 ± 0.00041 for the Type 119 (standard) elements, and 0.76636 ± 0.00044 for the Type 424 (thin) elements. The staff results for a water quantity of 4600 grams water significantly exceeded 0.95 for the Type 119 fuel elements, confirming that any additional water in the packaging increases k-eff for the single package analysis. Therefore the staff recommends that the approval be conditioned to clarify that the total mass of water or moderating materials in the package must be within the maximum masses evaluated by the applicant.

CONDITIONS

Based on the results of staff's review and independent analyses, the staff recommends that the following additional conditions be included in the U.S. DOT revalidation of French Certificate of Approval No. F/313/B(U)F-96, Rev. Hag:

1. For Content No. 11, the maximum fissile mass not to exceed 5 kilograms U-235 per package. The mass of water must not exceed 2000 grams per package in the form of moisture content of wood. No hydrogenous packaging materials are permitted within the package containment vessel.
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CONCLUSIONS

Based upon our review, the statements and representations in the documents described above, and for the reasons stated in this safety evaluation report, we agree that the TN-BGC1 package, as described in French Certificate of Approval No. F/313/B(U)F-96, Rev. Hag, meets the requirements of paragraph 680 of International Atomic Energy Agency (IAEA) "Regulations for the Safe Transport of Radioactive Material," TS-R-1, 1996 Edition (Revised), for Content No. 11 and Content No. 26, as limited in U.S. Department of Transportation Competent Authority Certificate USA/0492/B(U)F-96, Revision 9, with the conditions listed above.

Issued with letter to R. Boyle, Department of Transportation,
on ____12/27/2007__________ .