SAFETY EVALAUTION REPORT
Model No. RAJ-III Package
Japanese Certificate of Approval No. J/156/AF-96
Docket No. 71-3065

SUMMARY

By letter dated May 11, 2007, the U.S. Department of Transportation (DOT) requested that the Nuclear Regulatory Commission (NRC) review the Model No. RAJ-III package, as authorized by Japanese Certificate of Approval No. J/156/AF-96, Rev. No. 1. DOT requested that the NRC provide a recommendation concerning revalidation of the certificate for import and export use. DOT provided Global Nuclear Fuel – Japan Co., Ltd., document entitled “Safety Analysis for Type RAJ-III Nuclear Fuel Packages,” dated August 2006, and supplemental information.

The staff evaluated the package design against the standards in International Atomic Energy Agency (IAEA) “Regulations for the Safe Transport of Radioactive Material,” Safety Standards Series No. TS-R-1, 1996 Edition. Based on the statements and representations in the Safety Analysis Report and supplemental information, and for the reasons stated below, the staff recommends that DOT revalidate the certificate for import and export use, with the following additional conditions:

1. Transport by air is not authorized.
2. Lid lifting fixtures must be rendered incapable of being used for package lifting and tie-down during transport.
3. Package closure bolts must be adequately secured and torqued to prevent loosening during transport. Minimum and maximum torque values should be included in package operating procedures.

EVALUATION

1. GENERAL INFORMATION

1.1 Packaging Description

The Model No. RAJ-III package is designed for the transport of unirradiated boiling water reactor (BWR) fuel rods. The packaging is composed of two main components: an inner container that holds the fuel rods, which are contained within rod boxes, and an outer container that provides impact protection.

The inner container is a double-thin-walled stainless steel box that incorporates alumina thermal insulator between the double-walled construction. The outer container is constructed of a thin outer wall of stainless steel with balsa wood and resin-impregnated paper honeycomb inside to support the inner container. The outer container is also equipped with a shock absorbing suspension mechanism to protect the fuel rods from excessive vibration loads. The fuel rods are positioned within rod boxes, called protection cases.

The approximate dimensions and weights of the package are:

Overall width	73 cm
Overall height	74 cm
Overall length	507 cm
Weight of packaging	920 kg
Maximum weight of package, including contents	1490 kg

1.2 Drawings

The packaging is constructed and assembled in accordance with the following Global Nuclear Fuel – Japan Drawings:

TTO-T06-047-01, Sheets 1-6, Rev. 0	Structure of Outer Container (RAJ-III)
TTO-T06-047-02, Sheets 1-6, Rev. 0	Structure of Inner Container (RAJ-III)
TTO-T06-047-03, Sheet 1, Rev. 0	Structure of Shock Absorber (RAJ-III)

The fuel rod boxes are constructed and assembled in accordance with Figure (A)-D.3 for protection case Type I, and Figure (A)-D.4 for protection case Type II.

1.3 Contents

The authorized contents are specified in Japanese Certificate of Approval No. J/156/AF-96, and are described below:

1.3.1 Type and form of material

Unirradiated fuel rods composed of uranium oxide fuel pellets within fully welded zirconium alloy cladding tubes. The fuel rods may be either 8x8 or 9x9 fuel types with the following characteristics:

Type of fuel rod	8x8 standard rod	9x9 standard rod	9x9 short rod	9x9 tie rod
Fuel rod length (mm)	4,168	4,168	2,660	4,205
Max. effective fuel length (mm)	3,708	3,708	2,163	3,708
Clad tube inner diameter (mm)	10.55 ± 0.05	9.736 ± 0.05		
Clad tube wall thickness (mm)	0.86 ± 0.08	0.71 ± 0.08		
Max. outer pellet diameter	10.38	9.575		
Max. uranium enrichment	5.0 weight percent U-235			
Number of gadolinia-containing fuel rods	Not restricted			

1.3.2 Maximum quantity of material per package

The number of fuel rods per rod box is limited as follows:

Rod Box (Protective Case) Type I – A maximum 46 fuel rods of the 8x8 type.

Rod Box (Protective Case) Type II – A maximum 46 fuel rods of the 8x8 type, or a maximum 52 fuel rods of the 9x9 types.

Although the fuel rods of the three 9x9 types may be mixed within a single rod box, fuel rods of the 8x8 type may not be mixed with 9x9 type fuel rods within a single rod box.

For rod boxes that do not contain a full load, dummy stainless steel rods are substituted for missing fuel rods.

Maximum number of rod boxes (protective cases) per package: 2

The contents are limited to a Type A quantity of radioactive material. The impurities in the uranium are limited as follows:

Nuclide	Maximum Concentration
U-232	2×10^{-9} g/gU-235
U-234	1×10^{-2} g/gU-235
U-236	5×10^{-3} g/gU-235
Tc-99	2×10^{-7} g/gU-235

1.3.3 Criticality Safety Index (CSI)

The Criticality Safety Index (CSI) for the package is 0.25*.*

2. STRUCTURAL EVALUATION

The structural evaluation of the package is presented in Section (B)-A of the Safety Analysis Report. Section (B)-A.1 presents the structural design, including design standards, Section (B)-A.2 presents weights and center of gravity, Section (B)-A.4 addresses general standards for all packages, Section (B)-A.5 presents the evaluation of the package under normal conditions of transport, and Section (B)-A.6 presents the evaluation under accident conditions, including the 9-meter drop test (drop I), the puncture test (drop II), the thermal test, and immersion tests.

Evaluation of the RAJ-III package against the relevant section of IAEA TS-R-1, 1996 (as amended in 2003) is provided below with the relevant paragraph number of TS-R-1 identified.

606 – An adequate physical description of the package is provided in Section (A)-C of the application, along with the figures and tabular data for the packaging. The design meets the requirements of this paragraph.

607 – The structural design of the lifting system to be used to assemble, disassemble, and move the package is provided in Section (B)-A.4.4. The entire package is designed to be handled either by crane with wire-rope slings, or by forklift. Structural calculations have been provided for the various lifting conditions of the components of the package that have addressed

induced bending stresses; however, the shear stresses induced through the body of the outer container have not been identified in the calculations for either mode of handling. This requirement has not been fully demonstrated by analysis to have been met. However, supplemental steel members are provided on the bottom of the outer container in these locations that will provide additional shear capacity. In addition, previous handling of the package to date has not resulted in any known failures or identified deficiencies. Handling experience to date does not quantify the margin against failure, but there is reasonable assurance that the actual lifting loads can be resisted by the packaging.

608 – The outer container lid possesses sling fittings for the removal of the outer lid, and these are marked as, "exclusive use for lid lifting only." This requirement has only been addressed through administrative procedures as an administrative control on the user and not by physical configuration of the packaging. This may not be in conformance with the requirements, which specifies that the attachments must be designed to support the package mass, or shall be removable or otherwise rendered incapable of being used during transport. The approval should be conditioned to specify that the lid lifting fixtures are rendered inoperable for package lifting during transport.

610 – The stainless steel skin of the outer container, as described in Section C.2.2 of the application, provides for a free draining packaging that should not result in the retention of water. This requirement has been met.

612 – The packaging has been designed to withstand the effects of accelerations and decelerations that could reasonably be expected to occur during the transport and handling. Vibration effects on bolted closures have not been addressed in detail in Section A.4.7. Figures (A)-C.2 and (A)-C.3 and Sections C.2.1 and C.2.2 identify that the closure of the inner and outer containers is accomplished with bolts. No information is provided that indicates any special considerations have been made regarding the assurance that these bolts will not loosen during the transportation conditions. It is noted that the closure bolts for the two types of fuel rod protective cases also do not appear to have had any special considerations made regarding bolt loosening during transport. It is recommended that a minimum and maximum bolt torque value be included in the package operating procedures. The range of values should be based on the analytical method used in which the torque induced bolt tensile stresses were considered when analyzing the total bolt stresses under the accident conditions. It is noted in Section (D)-A.1.2.(9) that after the outer lid is placed, the procedure is to "tighten the bolts securely." A condition has been proposed to address the adequate tightening of the closure bolts.

615 – The design of the packaging for pressure and temperature is addressed in Sections A.4.2, A.4.6, and A.5.1. Computed stresses are within the appropriate allowable values and this requirement has been met. The air transport requirements of Paragraphs 617, 618, and 619 have not been addressed. The approval should be conditioned to prohibit air transport.

634 – The physical dimensions of the packaging meet this requirement.

635 – The lead seal and seal pin configuration meets this requirement.

636 – The tie-down system is not part of the packaging, but wire-rope is used on the outer container configuration as well as an enclosing rack system for truck transport. The tie-down system and rack system used are compatible with the packaging design. This requirement is met. It is noted that the lid lifting fixtures were not evaluated for package tie-down, and

therefore the lid lifting fixtures must be rendered inoperable for package tie-down during transport.

638 – The design and manufacturing techniques relative to the structural materials and their fabrication are in accordance with recognized standards. The reference to the U.S. stainless steel known as 304L does not have physical properties (stress limits) that are consistent with the Safety Analysis Report's current material table values, however, there is reasonable assurance that this type of stainless steel (304L) would be acceptable as a material of construction for this design.

717 – The prototype tests, except for the penetration test, were performed on a target that complies with these requirements. The target consisted of a substantial reinforced concrete mat of 3 feet-9 inches thickness, covered with a 1-1/4-inch thick steel plate. The penetration target complied with Paragraph 727(b).

719 – The water spray test was not performed since all materials exposed are not subject to degradation or soaking effects over short durations. The stacking effects were evaluated analytically as well as the penetration effects under normal conditions. Prototype free drop tests were performed. These requirements are considered to have been met.

720 – The test was not performed based on the outer container materials. This is acceptable.

721 – The test was not performed based on the outer container materials. This is acceptable.

722 – Free drop tests (three orientations) from 1.2 meters, after a corner drop from 0.3 meter, were performed for this package with a mass of less than 5000 kg. This requirement is considered to have been met.

723 – This requirement was addressed by analysis, since the metallic structure could be realistically modeled and analyzed. This requirement is considered to be met.

724 – This requirement was addressed by analysis, since the metallic structure could be realistically modeled and analyzed. This requirement is considered to be met.

726 – The mechanical free drop tests for accident conditions were performed prior to the thermal test. This requirement has been met.

727 – For this packaging, the provisions of Paragraph 727(a) and (b) were applied requiring a free drop of 9 meters onto the proper target so as to suffer the maximum damage. There were two specimens tested after each had been subject to the 0.3-meter and 1.2-meter free drops required for normal conditions for fissile material packages. One specimen was subjected to a 9-meter free drop on the flat steel plate of the target so as to strike the bottom face upper corner, and then was dropped again to impact on the opposite end of the packaging with the end essentially horizontal. A second specimen was subjected to a 9-meter free drop on the flat steel plate of the target so as to strike the lid face in the horizontal position. This specimen was then subjected to the 1-meter free drop onto the rigid vertical bar 15 cm in diameter and 20 cm long. While there was damage to the outer container, as well as the inner container, and some bending of fuel rods, no rupture of the rods occurred.

729 – Water will enter this packaging and can be in contact with the new fuel. By analysis the water pressures exerted on the new fuel cladding tube will be less than the pressure conditions caused under the general test conditions. The intent of this requirement has been met.

2.1 MATERIALS EVALUATION

The RAJ-III package is a Type A package. The contents are unirradiated Zircaloy-2 clad fuel rods as individual rods. A maximum of 1 percent gadolinium in the form of Gd_2O_3 is allowed in the fuel. The rods themselves act as the containment boundary. The packaging materials consist of austenitic stainless steel structural materials, alumina silicate thermal insulator, polyethylene foam cushions for the rods, natural rubber gaskets, and both balsa wood and resin-impregnated paper honeycomb for shock absorption.

The materials are listed by component in Table (A)-C.2. Most mechanical properties of the materials are listed in Table (B)-A.3, while thermal characteristics such as thermal expansion coefficients, and gas fill pressures were scattered throughout the Safety Analysis Report. The mechanical properties (yield, tensile, modulus, and density) agree well with other references for the stainless steel and Zircaloy-2. In addition, the thermal expansion of the Zircaloy-2 was checked and found to be acceptable. The properties of the balsa were verified against an online materials database. The bending strength of the alumina thermal insulator was close to indicated (314 MPa is quoted vs. 330 MPa, as referenced) but the quoted compressive strength of 294 MPa was an order of magnitude lower than the reference value of 2100 MPa. While there is an apparent discrepancy in the compressive strength, the alumina will stay intact under a compressive load to a higher extent than analyzed.

No information was found for the lumber (red tide) or the resin impregnated shock absorbing honeycomb paper so the properties of these materials, especially the applicable operating temperature range, could not be verified. The polyurethane cushioning foam was of such low density that no information appears readily available. The compressive strength for higher density foam varies over the operating temperature range from 120 to 80 percent of the room temperature strength indicating that there is reasonable assurance it can operate adequately over that range. Since there are no issues for the package except criticality in which these materials do not play a role, and since the rods themselves maintain containment, the properties of these materials are considered adequate for performing their function in transport.

Evaluation of the materials against the relevant sections of TS-R-1 is given below. The relevant conditions of TS-R-1 are met. Based on a review of the materials properties of importance, as described in the Safety Analysis Report, and comparison of the ability of the materials used in the package to meet the relevant sections of the TS-R-1, the staff agrees that the materials are adequate for their intended purposes.

Evaluation of the RAJ-III package against the relevant section of IAEA TS-R-1, 1996 (as amended in 2003) is provided below with the relevant paragraph number of TS-R-1 identified.

613 – This requirement addresses chemical and physical compatibility of materials of the packaging and contents. Table (B)-A.5 lists all the dissimilar materials that are in mutual contact. In no case is there an incompatible combination.

637 – This paragraph requires that there is no potential degradation of packaging material from -40°C to +70°C. The packaging materials consist of austenitic stainless steel, alumina silicate, polyurethane foam, natural rubber, balsa wood, and a resin-impregnated paper honeycomb.

The steel and alumina do not become brittle within this temperature range. Natural rubber in general has a suggested operating range of -30 to +76°C. The lower end does not quite appear to meet the -40°C operational range specification; however, the rubber gasket does not provide a safety function in transportation, since water inleakage is assumed in the criticality analyses.

638 – This requires the applicant to specify design and manufacturing techniques in accordance to national and international standards. The Safety Analysis Report states that either Japanese Standards (JIS) or American Standards (ASTM, etc.) may be used as long as the standard is applicable within the range of parameters that the packaging will be subjected to.

639 – This requires that the containment system cannot be opened by pressure arising within the system. The fresh fuel rods are pressurized to a maximum of 1.115 MPa which is typical for a newer vintage of boiling water reactor fuel rod. The applicant presented an analysis that showed that the hoop stress generated within the rod when the temperature is raised to 445°C is less than the yield strength of the zirconium alloy cladding. No breach of the cladding is expected. All the welds used in forming the fuel rods are subjected to either x-ray or ultrasonic testing to confirm integrity.

642 – The design of the containment system shall take into account generation of gas by chemical reaction and radiolysis. For this package the containment boundary is the fuel rod. The UO_2 pellets are contained in a helium atmosphere in a zirconium alloy tube that is welded shut. There are no radiological or chemical interactions that would take place within the rod that would generate gas. The generation of fission gas prior to irradiation is minimal.

645 – This requirement specifies that the radiation shield must be designed so there is no unintentional release of the component; however, there is no applied shielding in this package.

671(a)(iii) – There must be no loss of efficiency of built in neutron absorbers or moderators. There is no specific component intended to act as a neutron absorber or moderator in this package.

3. THERMAL EVALUATION

The thermal evaluation of the package is presented in Section (B)-B of the Safety Analysis Report. Sections (B)-B.1 through 3 present the thermal design, including thermal properties of materials and material specifications. Section (B)-B.4 presents the evaluation of the package under normal conditions of transport, and Section (B)-B.5 presents the evaluation under accident (fire) test conditions.

The contents of the package consist of unirradiated uranium dioxide fuel rods. The decay heat of the contents is negligible. The thermal evaluation of the package was performed using a combination of analytical calculations and an experimental (furnace) test of the package.

The applicant performed thermal analysis for normal conditions using analytical methods. For accident (fire) conditions, a furnace test was performed. The thermal design of the package, conditions of the analyses and test, analysis models, and experimental procedures, are included in the Safety Analysis Report. The thermal analysis was used to verify that the fuel cladding tube is intact (thermal stress and thermal expansion) under normal conditions of transport and accident conditions (called special test conditions in the application). The thermal analysis also verified that the inner container fuel and moderator configuration remained in agreement with the analyzed configuration assumed in the criticality analyses.

The contents of the RAJ-III package are unirradiated fuel rods, whose decay heat is negligible. Two layers of packaging (the inner and outer containers) are designed to fulfill thermal requirements. Particularly, an alumina thermal insulator is used between the stainless steel (SUS304) double walls of the inner container to resist the fire test condition. The material thermal properties at room temperature and operational temperature limits are listed for the analysis. The staff has verified that temperature dependency on the thermal properties is taken into account in the calculation. For the normal condition thermal analysis, an ambient temperature of 38°C and solar radiation heat transfer required by IAEA regulations were posted as boundary conditions to reach the maximum temperature and maximum operating pressure. In the fire test, after being in equilibrium with the 38°C environment, a full size test package was subjected to an 800°C environment in a furnace, for more than 30 minutes. Procedures in both the normal condition and accident thermal analyses follow the IAEA regulations. The accident condition thermal analysis initial condition did not appear to address damage that might be incurred due to the 9-meter drop and puncture tests. The staff notes, however, that the full scale test specimen used in the furnace test had been subjected to these tests. The analysis results are summarized to demonstrate the IAEA requirements are met and no thermal stress limit violation.

For the normal condition evaluation, a lumped capacity analytical method was used to estimate the maximum temperature and pressure. In the steady state condition, the solar heat is balanced by the natural convection and radiation heat. A turbulence model of natural convection heat transfer correlation was employed for the ceiling surface and a laminar correlation was used for side surfaces. In the application, a constant heat flux correlation was used for the maximum temperature calculation on the side surfaces, which is different from an isothermal approach on the ceiling surface. No justification was provided for this difference. However, based on the margin of safety with respect to maximum temperatures, and the conservatism built into the analysis, the results were considered acceptable.

The absorption coefficient of 0.3 for the outer container surface was assumed for conservatism (normally 0.1). Solar insolation of 800 W/m^2 for the ceiling surface and 200 W/m^2 for side surfaces were imposed on the package according to paragraph 654 of the IAEA regulations. The maximum temperatures obtained were 81.2°C for the ceiling surface, and 55.5°C for side surfaces. These temperatures were below the 90°C temperature limit for the fuel cushioning material (foam polyethylene).

Based on Boyle's Law, at a temperature of 82°C, the maximum fuel rod internal pressure was calculated as 1.35 MPa (9x9 rods) and 0.74 MPa (8x8 rods). The radial stresses were calculated as 11.35 MPa and 4.99 MPa, respectively, which are well below the zirconium alloy yield strength limit 343 MPa. Although no derivation was provided for how the numerical value of 343 MPa for zirconium alloy yield strength was obtained, there is reasonable assurance that the integrity of the fuel cladding tubes is maintained. For minimum temperature test (-40°C), the applicant did not provide details of impact analysis of the cold environment, however, the materials of construction are compatible with this low temperature (see Materials Evaluation, above).

For the normal conditions thermal evaluation, there was no experimental test to verify the analytical results, however, staff has reasonable assurance that the package provides adequate thermal design under normal conditions of transport.

For accident conditions, a furnace test was performed using a full scale test package. The test package had previously been subjected to the drop and puncture tests. The thermocouple locations and furnace dimensions are described in the application. The staff notes that there is a typographical error in the furnace dimensions given in Section (B)B.5.1.2(3) of the application, since the furnace interior height reported (200 mm) is smaller than the height of the package (722 mm). Twenty-five thermocouples were attached in various locations across the entire test package. The test package was heated until the outside surface thermocouple temperatures reached 800°C or above, then the 30-minute test period was started. More than 30 minutes of heating was conducted. Afterwards, the test package was brought out of the furnace for cooling. The maximum temperatures obtained were:

Location	Maximum Thermocouple Temperature
Outer Container – outside surface	877°C
Outer Container – inside surface	821°C
Inner Container – outside surface	809°C
Inner Container – inside surface	401°C
Contents	271°C

Some uneven temperature distribution was observed from the temperature plot. Although some measurement data and analyses were not well explained, the overall results of the furnace test, along with large margins in the allowable fuel rod cladding stresses, provided reasonable assurance that the thermal requirements of IAEA TS-R-1 were met. Since the focus is the integrity of contents, to be conservative, the applicant used the inner container inside temperature (401°C) as the maximum temperature for the fuel. An additional temperature correction (44°C) for solar heating (using the normal conditions high temperature analysis results) was added to the measured container inner temperature to give a best estimate of maximum temperature of the fuel contents, which was 445°C. It was observed that a part of the fuel assembly packaging material, polyethylene separators, etc., had partially melted down and stuck to fuel rods in the furnace test. The applicant's criticality analysis, however, did consider full moderation from polyethylene. Again, based on Boyle's Law, for a temperature of 445°C, the maximum internal pressure was calculated as 2.74 MPa (9x9 rods) and 1.49 MPa (8x8 rods). The radial stresses were calculated as 23.37 MPa and 10.84 MPa, respectively, which were well below the zirconium alloy tensile strength limit of 210 MPa. Although no explanation was given in the application why tensile strength was used as the limit for the radial stress comparison, there is reasonable assurance that the integrity of the fuel rod cladding tubes is maintained.

Based on review of the statements and representations in the application, the staff concludes that the thermal design has been adequately described and evaluated, and the thermal performance of the package meets the thermal requirements of IAEA TS-R-1 regulations.

4. CONTAINMENT EVALUATION

The containment evaluation is presented in Section (B)-C of the Safety Analysis Report. The primary containment boundary is stated to be the fuel rod cladding. The fuel rods are fully welded structures made of zirconium alloy. As described in Section (A)-D.2.4 of the Safety Analysis Report, each fuel rod is back-filled with helium gas and leak tested after welding. Each closure weld is also examined by X-ray or ultrasonic testing to confirm its integrity. The structural integrity of the fuel rods was confirmed by subjecting the rods to helium leak testing, after the test package was subjected to the accident test sequence. The Safety Analysis Report provides information that shows that the fuel rods remain leak tight under normal and accident conditions (Sections (B)-A.6.1.5 and (B)-C.5).

5. SHIELDING EVALUATION

The shielding evaluation is presented in Section (B)-D of the Safety Analysis Report. The contents of the package consist of unirradiated uranium dioxide fuel rods. The external radiation at the package surface is therefore small, and no special radiation shielding components are needed in the package. The staff agrees that no additional shielding is needed to meet the external radiation standards in TS-R-1. In addition, external radiation measurements are taken of the inner container after loading prior to each shipment, as specified in the package operations described below.

6. CRITICALITY EVALUATION

The criticality evaluation is presented in Section (B)-E of the Safety Analysis Report. The modeling of the fissile contents and packaging for the criticality analyses is described in Section (B)-E.3. The criticality assessment, including results, is provided in Section (B)-E.4. The objective of the criticality review is to verify that the package design satisfies the criticality safety requirements of IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1) under normal conditions of transport and hypothetical accident conditions. These objectives include a review of the criticality design criteria, packaging features, and fuel specifications; a review of the fuel configuration; and a review of the criticality analyses including verification of neutron multiplication factors calculated in the application

The staff reviewed the RAJ-III criticality safety analysis to ensure that all credible configurations for normal and accident conditions had been identified and their potential consequences on criticality appropriately considered. The evaluation was to ensure that the package meets the requirements in TS-R-1 for fissile material packages, including paragraphs 671, 673 through 679, 681, and 682. The applicant did not provide an assessment of the package against the requirements of paragraph 680; therefore air transport should not be authorized.

6.1 Description of Criticality Design

The RAJ-III package is composed of an inner container and an outer container, both of which are constructed of stainless steel. The inner container has a double-walled stainless steel sheet structure with an alumina thermal insulator filling the gap between the two walls. The outer container has a stainless steel framework which is fitted with stainless steel plates. In addition, the package has a balsa and honeycomb-type paper material used as a shock absorber. The inner container has an inner container body, an inner container lid, and an end lid.

Two types of fuel rod boxes (called protection cases) are used within the inner container: Type I and Type II. The rod boxes are comprised of two parts – the case body and lid – both of which are stainless steel. There are two rod boxes inside of the inner container, separated by a 0.2-cm thick stainless steel partition.

The Type I case is used for transport of 8x8-type fuel rods. The Type II case is used to transport 8x8 or 9x9-type fuel rods.

6.2 Nuclear Fuel Contents

The unirradiated fuel rods consist of uranium dioxide. The maximum uranium enrichment is 5.0 weight percent. The Type I rod box contains a maximum of 46, 8x8-type rods. The Type II rod box contains a maximum of 46, 8x8-type rods, or 52, 9x9-type rods.

The fuel rods are composed of uranium dioxide pellets, a fuel cladding tube, upper and lower end plugs, etc. A description of the rods is shown in Table (A)-D.4 of the application.

6.3 General Considerations for Criticality Evaluations

The applicant performed analyses for a single package and for array configurations under conditions as described in paragraphs 677 (single package in isolation), 681 (arrays of packages under normal conditions of transport), and 682 (arrays of packages under accident conditions of transport) of TS-R-1. The results of these analyses were presented in tables that showed the calculated k-effectives and their standard errors. Although the applicant did not formally establish an upper safety limit as part of the criticality evaluation, the results show a k-eff (including a statistical error of 3σ) of well below 0.90 under both normal conditions of transport and accident conditions. Staff reviewed these tables and found that the most reactive cases were clearly indicated, and were demonstrated to be subcritical

6.4 Criticality Safety Evaluation

The drop tests showed only a minor decrease in the height of the outer container, but no measurable impact on criticality safety. Therefore the normal and accident conditions analytical models were the same with the following exceptions:

- The undamaged cases assumed no flooding of the outer or inner containers. It was assumed that water surrounds the package in both the single package and array models.

- For the damaged packages, it is assumed that flooding occurs within the inner and outer containers, as well as inside the rod boxes.

In the accident conditions cases, the rod boxes were modeled with polyethylene inside, instead of water. In Appendix (B)-E.2, the effects of water and polyethylene on moderation was discussed, and polyethylene was determined to produce a higher reactivity than water for this system. The staff confirmed by analysis that moderation by polyethylene is more conservative.

The maximum k-effs calculated by the applicant are shown below:

Package condition	Rod Box Type	Fuel Rod Type	Maximum k-eff + 3σ
Single damaged package in isolation	Type I	8x8-type	0.598
	Type II	8x8-type	0.617
	Type II	9x9-type	0.622
Array of undamaged packages	Type I	8x8-type	0.706
	Type II	8x8-type	0.709
	Type II	9x9-type	0.717
Array of damaged packages	Type I	8x8-type	0.823
	Type II	8x8-type	0.829
	Type II	9x9-type	0.835

The applicant did not consider moderation (water or polyethylene) within the fuel cladding. The staff does not agree that water should not be considered, even in the case where the fuel rod cladding is leak tight. However, because the applicant provided a conservative evaluation that considered optimum moderation by polyethylene, as well as optimum spacing of the fuel rods within the fuel rod boxes, and because the analyses show large margins against criticality, the staff agrees that this would not result in an unacceptably large increase in k-eff for the damaged package analyses. In addition, the applicant did not provide a benchmark analysis. Because of the large margins to criticality the staff did not request such an analysis from the applicant.

The applicant performed analyses and determined the criticality calculation results to be subcritical as shown in Section E.4.5 of the application. The staff performed confirmatory calculations, including analyses for damaged and undamaged packages. The staff used a more conservative model than that used by the applicant, in that packaging materials used for thermal and impact protection were neglected. This was to allow water moderation to a greater degree. In addition, the model used a length equivalent to the active fuel length. These conservative analyses confirmed that the package remains subcritical under normal and accident conditions.

6.5 Criticality Safety Index

The Criticality Safety Index for the package is 0.25, as specified in the Japanese Certificate. For normal conditions of transport, an array of 1080 (5N) undamaged packages, surrounded by 20 cm of water, was considered. For the array of damaged packages, 432 (2N) packages were modeled and shown to be subcritical. Based on the requirements of paragraphs 681, 682, and 528 of TS-R-1, the Criticality Safety Index for the package was confirmed to be appropriate.

6.6 Conclusion

Based on the review of the information and representations made by the applicant in the Safety Analysis Report and supporting information, the staff finds reasonable assurance that the package design with the proposed contents meets the criticality safety requirements for fissile material packages in TS-R-1.

7. PACKAGE OPERATIONS

Package operations (handling methods of the package) are presented in Section (D)-A of the Safety Analysis Report for the package. These methods address loading the fuel rods into the rod boxes (protection cases), loading the rod boxes into the inner containers (which may be performed either before or after the rods are loaded), and loading of the inner container into the outer container. The handling methods include securing packaging fasteners, attaching tamper-indicating seals, and performing contamination and radiation surveys.

Leakage testing of the fuel rods is described in Section (B)-C.2 of the Safety Analysis Report. Each individual fuel rod is backfilled with pressurized helium as part of the manufacturing process, and is tested for helium leakage. In addition, each fuel rod is subjected to X-ray or ultrasonic inspections to confirm the integrity of the closure welds.

Figures (A)-C.2 and (A)-C.3 and Sections C.2.1 and C.2.2 identify that the closure of the inner and outer containers is accomplished with bolts. Rod boxes are also closed with bolts. No information is provided that indicates any special considerations have been made regarding the assurance that these bolts will not loosen during the transportation conditions. It is recommended that a minimum and maximum bolt torque value be included in the package operating procedures. A condition has been proposed that specifies that package closure bolts must be adequately secured and torqued to prevent loosening during transport, and that minimum and maximum torque values should be included in package operating procedures.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The acceptance tests are described in Section B of the reference document entitled “Description of Outlines on Manufacturing Method of the Packaging.” The acceptance tests include component and material inspections for steels, bolts, nuts, bars, wires, and special materials such as the alumina thermal insulator, polyethylene foam, balsa, paper honeycomb, natural rubber, etc. Acceptance tests also include dimensional inspections, welding inspections, load tests for the lifting slings, and confirmation of packaging weight. These are considered adequate.

The maintenance program for the package is presented in Section (D)-B of the Safety Analysis Report for the package. The maintenance consists primarily of visual inspections of the inner and outer containers that are performed at least once every year or every 10 shipments. This maintenance program is considered adequate to assure packaging effectiveness throughout its service life.

CONDITIONS

Based on the staff’s review, the staff recommends that DOT revalidate the certificate for import and export use, with the following additional conditions:

1. Transport by air is not authorized.
2. Lid lifting fixtures must be rendered incapable of being used for package lifting and tie-down during transport.
3. Package closure bolts must be adequately secured and torqued to prevent loosening during transport. Minimum and maximum torque values should be included in package operating procedures.

CONCLUSIONS

Based on the statements and representations presented in the Safety Analysis Report and supplemental information, the staff agrees that the package meets the standards in IAEA Safety Standards Series No. TS-R-1, 1996 Edition. The staff recommends that DOT revalidate Japanese Certificate of Approval No. J/156/AF-96, Rev. No. 1, for import and export use, with the conditions listed above.

Issued with Ltr. to R. Boyle
dated 1/15/2008.