SAFETY EVALUATION REPORT
Docket No. 71-3036
Model No. JRF-90Y-850K
Japanese Certificate of Competent Authority J/2039/B(U)F

SUMMARY

By letter January 12, 2022 (Agencywide Documents Access and Management System Accession No. ML22063B110), as supplemented on February 09, 2022 (ADAMS Accession No. ML22063B159), requesting the U.S. Nuclear Regulatory Commission (NRC) assistance in evaluating the Model No. JRF-90Y-950K package as authorized by the Japanese Certificate of Competent Authority J/2039/B(U)F, dated December 20, 2021, and make a recommendation concerning the revalidation of the package for import and export use. Specifically, the U.S. Department of Transportation (DOT) requested NRC review the content described in Table 3, "Specification of Content (Spectrum Converter)" of the Japanese certificate. The NRC reviewed the application, as supplemented, against the requirements in International Atomic Energy Agency (IAEA) Specific Safety Requirements, No. SSR-6, Revision 1, "Regulations for the Safe Transport of Radioactive Material," (SSR-6, Rev. 1).

In support of this request, the DOT provided the following documents for review with its letter dated January 12, 2022:

1. Japanese Certificate of Competent Authority J/2039/B(U)F, dated December 20, 2021,

2. Kyoto University application "Safety Analysis Report of JRF-90Y-950K," as supplemented, and

3. Kyoto University Quality Management System for Transport Containers.

The NRC previously reviewed and recommended revalidation of Japanese Certificate of Competent Authority J/2039/B(U)F for the Model No. package by letter dated January 29, 1999 (ADAMS Accession No. ML023080337). The package was subsequently reviewed and recommended for revalidation by letter dated August 31, 2010 (ADAM Accession No. ML102440020). Based upon our review, the statements and representations contained in the application, and for the reasons stated below, we recommend revalidation of Japanese Certificate of Competent Authority J/2039/B(U)F, dated December 20, 2021, for the Model No. JRF-90Y-950K transport package.

1.0 GENERAL INFORMATION

The Model No. JRF-90Y-950K is a Type B fissile package designed for the transport of research reactor fuel and other experimental components containing fissile material. The packaging consists of the main body and basket.

1.1 Packaging

The main body consists of an inner and outer shell is filled with a rigid polyurethane foam that acts as both a shock absorber and thermal insulator. The packaging body is cylindrical in shape and consists of a 10-mm-thick radial, stainless steel shell and a 35-mm-thick stainless steel bottom plate. The bottom plate is welded to the inner shell. The outer shell is constructed of a 3-mm-thick radial, stainless steel shell and a 6-mm-thick stainless steel bottom plate. The outer bottom plate is welded to the outer stainless steel shell. Between the inner and outer shells, the radial region of the main body is filled with rigid polyurethane foam. The upper and lower axial regions of the main body are also constructed of the same inner and outer shells, however the region between the two shells at the top and bottom of the packaging is filled with balsa wood. The inner shell is closed with a 55-mm -thick stainless steel lid which is fastened to the inner lid shell onto the top of the inner shell by 16, M24 bolts. Between the inner lid and inner shell are two ethylene propylene rubber O-rings which provide containment and a leak testable port.

The spectrum converter is positioned within a stainless steel fuel basket. The approximate dimensions and weights of the package are:

Overall height: 1800 mm
Overall diameter: 840 mm
Containment vessel height: 1310 mm
Containment vessel diameter: 460 mm
Maximum weight packaging: 860 kg
Maximum package weight, with contents: 950 kg.

1.2 Contents

The applicant requested approval of a spectrum converter plate as authorized contents. The spectrum converter is a disc shaped fuel element which has a diameter of 310 mm and is 10.7 mm thick, with a maximum enrichment of 90 weight percent uranium-235 (^{235}U). The plate's fuel meat is 9.22 mm thick uranium dioxide encased in 0.7-mm-thick aluminum alloy. The spectrum converter has a maximum burnup of 7.00×10^{-6} percent ^{235}U, with a minimum cool time of 12,340 days and a heat generation rate of 5.13×10^{-6} Watts/package. The spectrum converter contains a maximum 1,002 grams ^{235}U per plate, and has a maximum weight of 2,500 g.

1.3 Criticality Safety Index

The criticality safety index (CSI) for the package containing the spectrum converter is 0.0.

2.0 STRUCTURAL EVALUATION

The objective of the structural evaluation is to verify that the structural performance of the JRF-90Y-950K package meets the requirements of IAEA SSR-6, Rev. 1. The NRC previously reviewed the structural performance of the JRF-90Y-950K package and recommended revalidation of Japanese Certificate. For this structural review, the NRC staff focused on the components of the package and the requirements of IAEA SSR-6, Rev. 1, that were affected by the addition of a spectrum converter as approved content for the JRF-90Y-950K package.

2.1 Description of the Structural Design

The applicant described the package in Chapter (I) of the JRF-90Y-950K Safety Analysis Report (SAR). As described in (I)-Table A.1 of the SAR, the spectrum converter is a uranium dioxide disk with an aluminum alloy cladding and has a maximum mass of 2500 grams. A maximum of one spectrum converter can be transported in the JRF-90Y-950K. (I)-Figure D.22 depicts the spectrum converter.

The fuel basket for the spectrum converter is shown in (I)-Figure C.9. The fuel basket has a disk-shaped portion attached to the upper part of the previously reviewed fuel basket for the JRF-90Y-950K. A single spectrum converter is loaded in the disk-shaped portion of the fuel basket with silicone rubber spacers. The staff notes that there are no other changes to the previously reviewed components of the package.

The staff finds that the applicant provided adequate descriptions of the structural design, consistent with the applicable structural requirements of IAEA SSR-6, Rev. 1, paragraphs 220, 607, and 809.

2.2 Normal Conditions of Transport

The requested change of adding the spectrum converter as approved content does not affect the structural performance of the previously reviewed components of the packaging under normal conditions of transport as prescribed in IAEA SSR-6, Rev. 1. The applicant evaluated the structural performance of the spectrum converter under the free drop test. The applicant's previously reviewed evaluations for the other normal conditions of transport are bounding or unaffected by the addition of the spectrum converter.

The applicant presented the structural evaluations of the spectrum converter for the free drop test in sections (II)-A.5.3(6)(c)-3, II-A.5.3(7)(b)-3, and II-A.5.3(8)(b)-3 of the SAR for the side, bottom-end, and top-down drop orientations, respectively. Following the previously reviewed methodology used in evaluating the Kyoto University Critical Assembly (KUCA) fuel contents, the applicant evaluated the structural performance of the spectrum converter using the previously determined design accelerations presented in section A.5.3(5) of the SAR. The applicant presented the stresses and safety margin with respect to yield stress resulting from the free drop test in (II)-Table A.16, (II)-Table A.17, and (II)-Table A.18 of the SAR for the side, bottom-end, and top-down drop orientations, respectively. For each drop orientation, the applicant calculated a safety margin greater than zero and determined that the spectrum converter had sufficient structural capacity to remain undamaged after the free drop test.

The staff reviewed the applicant's evaluation of the normal conditions of transport free drop test and finds that the requirements of IAEA SSR-6, Rev. 1, paragraph 722 have been met.

2.3 Accident Conditions of Transport

The requested change adding the spectrum converter as approved content does not affect the structural performance of the previously reviewed components of the packaging under accident conditions of transport as prescribed in IAEA SSR-6, Rev. 1. The applicant evaluated the structural performance of the spectrum converter under the mechanical test. The applicant's previously reviewed evaluations for the other accident conditions of transport are bounding or unaffected by the addition of the spectrum converter.

The applicant presented the structural evaluation for the mechanical test drop in section (II)-A.6.1 of the SAR. Following the previously reviewed methodology used in evaluating the KUCA fuel contents, the applicant evaluated the structural performance of the spectrum converter using the previously determined design accelerations presented in section A.6.1(4) of the SAR. The applicant presented the stresses and safety margin with respect to yield stress resulting from the mechanical test drop I in (II)-Table A.26, (II)-Table A.27, and (II)-Table A.28 of the SAR for the side, bottom-end, and top-down drop orientations, respectively. For each drop orientation, the applicant calculated a safety margin greater than zero and determined that the spectrum converter had sufficient structural capacity to remain undamaged after the mechanical test.

The staff reviewed the evaluation of the accident conditions of transport mechanical test and finds that the requirements of IAEA SSR-6, Rev. 1, paragraph 727 have been met.

2.4 Evaluation Findings

Based on the staff's review of the structural evaluation and related sections of the application, the staff concludes that the JRF-90Y-950K package with the additional spectrum converter content has sufficient structural capacity to meet the requirements of IAEA SSR-6, Rev. 1.

3.0 THERMAL EVALUATION

The objective of the thermal evaluation is to demonstrate that the package meets the thermal performance requirements of the IAEA SSR-6, Rev. 1, when evaluated for normal and accident conditions of transport as defined in the IAEA regulations. The JRF-90Y-950K package was originally issued a U.S. DOT certificate of competent authority, with the requisite review and approval by NRC. In that application, the applicant evaluated the thermal response of the package through prototype testing and analytical evaluation. The package was subsequently revalidated by NRC on August 21, 2010.

Requested changes include additional contents in the form of a spectrum convertor and changes to meet the requirements of the latest version of IAEA SSR-6, Rev. 1. The requested changes do not have any impacts on the current thermal performance of the package, since the spectrum converter is uranium fuel in an aluminum cladding, like the other research reactor fuel elements previously evaluated.

3.1 Normal Conditions of Transport

The thermal performance of the JRF-90Y-950K package with the newly defined contents, will have no effect on the thermal performance of the package and continues to be bounded under normal conditions of transport; therefore, the package meets the requirements of IAEA SSR-6, Rev. 1.

3.2 Accident Conditions of Transport

The thermal performance of the JRF-90Y-950K package with the newly defined contents, will have no effect on the thermal performance of the package and continues to be bounded under accident conditions of transport; therefore, the package meets the requirements of IAEA SSR-6, Rev. 1.

3.3 Evaluation Findings

Based on the staff's review of the thermal evaluation and related sections of the application, the staff agrees with the applicants' conclusion that the JRF-90Y-950K package meets the thermal standards of IAEA SSR-6, Rev. 1 for normal and accident conditions of transport.

4.0 CONTAINMENT EVALUATION

The objective of the containment evaluation is to demonstrate that the JRF-90Y-950K package meets the containment performance requirements of the IAEA transport regulations found in IAEA SSR-6, Rev. 1 when evaluated for normal and accident conditions of transport as defined in the IAEA regulations.

Requested changes include additional contents in the form of a "Spectrum Convertor" and changes to meet the requirements of the latest version of IAEA SSR-6, Rev. 1. The requested changes do not change the containment performance of the package.

4.1 Containment Boundary

There have been no changes to the containment boundary of the package; therefore, the staff's previous findings still apply.

4.2 Evaluation Findings

Based on the staff's review of the containment and other related sections of the application, the staff agrees with the applicant's conclusion that the JRF-90Y-950K package meets the containment standards of IAEA SSR-6, Rev. 1 for normal and accident conditions of transport.

5.0 SHIELDING EVALUATION

The applicant requested U.S. revalidation of the Certificate of Compliance for the Model No. JRF-90Y-950K package to the requirements of SSR-6, Rev. 1. The only significant change to the package design since the 2010 review is the addition of the spectrum converter as an allowable content.

The spectrum converter consists of a circular flat disk of uranium dioxide, with aluminum alloy cladding. The uranium dioxide in the spectrum converter is enriched up to 90 weight percent ^{235}U, with a maximum ^{235}U mass of 1.002 kilograms per package. Figure D.22 of the application shows the dimensions of the spectrum converter.

The activity of the spectrum converter is limited to 2.43×10^6 becquerels (Bq), which is equivalent to the activity of one JMTRC fuel element, which is also high enriched uranium. Since the previously approved shielding evaluation in letter dated January 23, 2003 (ADAMS Accession No. ML030240618), for the package considers the basket containing up to 10 Japan Material Testing Reactor Critical Assembly (JMTRC) fuel elements and demonstrates compliance with the external dose rate requirements of SSR-6, the applicant states that the package with the spectrum converter is bounded by the previously evaluated contents and will not exceed the SSR-6, Rev. 1 dose rate requirements.

The staff reviewed the certificate of compliance for the Model No. JRF-90Y-950K package, as well as the applicant's initial assumptions, model configurations, analyses, and results in the SAR. The staff finds with reasonable assurance that the package, with the requested contents, will meet the radiation dose rate requirements of IAEA SSR-6.

6.0 CRITICALITY EVALUATION

The applicant requested U.S. revalidation of the Certificate of Compliance for the Model No. JRF-90Y-950K package to the requirements of IAEA SSR-6, Rev. 1. The only significant change to the package design since the 2010 review is the addition of the spectrum converter as an allowable content.

The spectrum converter consists of a circular flat disk of uranium dioxide, with aluminum alloy cladding. The uranium dioxide in the spectrum converter is enriched up to 90 weight percent ^{235}U, with a maximum ^{235}U mass of 1.002 kilograms per package. Figure D.22 of the application shows the dimensions of the spectrum converter. Fuel material properties important for the criticality model are shown in Table E.6 of the application. The spectrum converter will be arranged on top of the existing package fuel basket, as shown in Figures C.9 and E.2 of the application.

The applicant modeled triangular pitched infinite arrays of packages under accident conditions of transport, each containing a spectrum converter. This evaluation bounds the single package in isolation and arrays of packages under normal conditions of transport, both of which would have a much lower system k_{eff} due to the lack of moderation under these conditions. This analysis also bounds the single package in isolation under accident conditions of transport.

The applicant modeled the package the same as for the previously approved analyses for other fuel contents, including assuming that all the gaps inside the packaging can be filled with water, and that the insulation in the packaging can be replaced with water. The applicant determined the optimum moderation by varying the water density within the package. The applicant's resulting maximum system k_{eff} plus three times the calculation Monte Carlo uncertainty (3σ) is 0.4001, which is significantly below the 0.95 acceptance criterion. Since the applicant demonstrated that infinite arrays of packages are subcritical, the criticality analysis supports a package CSI of 0.0.

The staff reviewed the configurations modeled by the applicant for the accident conditions array analyses. The staff finds that the applicant has identified the most reactive credible condition of the package, consistent with the condition of the package under normal and accident conditions of transport, and the chemical and physical form of the fissile and moderating contents.

For all evaluations of the package containing a spectrum converter, the applicant used the SCALE code system, with the KENO VI three-dimensional Monte Carlo neutron transport code and the 238-group ENDF/B-V cross section library, to determine system k_{eff}. The SCALE code system is a standard in the nuclear industry for performing Monte Carlo criticality safety and radiation shielding calculations and is therefore acceptable for this application. The applicant benchmarked the code and cross section used for the criticality analysis as discussed in Section E.5 of the application. The applicant's benchmark analysis evaluated 10 critical experiments which varied in materials, geometric configuration, and uranium enrichment. While the applicant did not calculate a code bias and bias uncertainty based on the results of this benchmark analysis, the applicant's maximum calculated k_{eff} for the package with the spectrum converter is significantly less than 0.95, and it would be significantly less than an Upper Subcritical Limit (USL) calculated based on the benchmarking analysis.

The applicant's benchmark analysis contained several deficiencies, when compared to U.S. NRC guidance on code benchmarking contained in NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages." These deficiencies include: 1) dissimilarities between critical experiments and the modeled system, including enrichment and fuel material; 2) no demonstration that the model is within the range of applicability of the selected experiments for key system parameters (e.g., enrichment, hydrogen to fissile ratio, energy of the average lethargy causing fission); 3) insufficient number of experiments modeled to determine code bias and bias uncertainty using normal statistics; 4) no analysis of code bias trends as a function of key system parameters; and 5) the calculated bias and bias uncertainty are not included in the final k_{eff} results. However, the staff finds the applicant's benchmark analysis to be sufficient in this case for the following reasons: 1) there is significant margin between the applicant's maximum calculated k_{eff} and the 0.95 acceptance criterion (>0.49 in k_{eff}); and 2) the applicant used a code (SCALE) that is a standard in the industry for performing criticality calculations, and it is unlikely that a code bias and bias uncertainty calculated for water moderated high-enriched uranium fuel plates in a package would be greater than the margin of subcriticality.

The staff reviewed the certificate of compliance for the Model No. JRF-90Y-950K package, as well as the applicant's initial assumptions, model configurations, analyses, and results in the SAR. The staff finds that the applicant has identified the most reactive configuration of the Model No. JRF-90Y-950K package with the requested contents, and that the criticality results are conservative and demonstrate that the package and package arrays will be subcritical. Therefore, the staff finds with reasonable assurance that the package, with the requested contents, will meet the criticality safety requirements of IAEA SSR-6, Rev. 1.

7.0 MATERIALS EVALUATION

The purpose of the materials evaluation is to verify that the materials performance of the Model JRF-90Y-950K package meets the regulatory requirements of IAEA SSR-6, Rev. 1. The staff's review was limited to the materials changes that occurred since the NRC's previous recommendation to revalidate the package. Specifically, the applicant requested the addition of the Kyoto University spectrum converter as allowable package contents.

SAR Chapters (I)-A(11), (I)-C(1) (I)-C(2.3), (I)-D(4), and (I)-Fig.C.9, (I)-Table C.2, (I)-Table A.1, (I)-Table D.4, and (I)-Fig.D.22 describe the new contents and packaging, specifically the spectrum converter and the associated fuel basket. The spectrum converter is described as a lightly irradiated high-enriched uranium fuel clad in an aluminum alloy. The associated fuel basket (Basket No. 2) holds the spectrum converter in its specified position and provides impact absorption through the use of silicone rubber spacers. The only substantial difference from the existing No. 1 fuel basket design is the introduction of a location at the top of the basket to hold the spectrum converter disk.

7.1 Mechanical Properties of Package Materials

The staff notes that no new materials are introduced, as the packaging materials are unchanged, and the spectrum converter is described as using the same A6061P aluminum material as the existing fuel element hold down part in (II)-Table A.4. Therefore, no material changes are introduced by this revision. However, the applicant revised the SAR to provide greater clarity with respect to the specific temper applied to the A6061P material ("T6" temper). The staff verified that the mechanical properties used in the applicant's structural analysis are consistent with that temper designation. Therefore, the staff finds the mechanical properties to be acceptable.

Based on the evaluations above, the staff finds that the package continues to meet the requirements of Paragraph 639 of SSR-6, Rev. 1.

7.2 Content Reactions

The staff notes that the additional contents described above are constructed of aluminum-clad uranium alloys that do not introduce any new potential corrosive or other reactions that were not considered for the previously approved uranium alloy fuel contents. The package transports the contents under dry conditions, and the atmospheric conditions surrounding the contents are compatible with the passive, corrosion resistant surfaces of aluminum and stainless steel that make up the fuel cladding and fuel basket assembly. Therefore, the staff finds the corrosion performance of the package with new fuel types to be acceptable.

Based on the evaluations above, the staff finds that the package continues to meet the requirements of Paragraph 614 of SSR-6, Rev. 1.

7.3 Content Integrity

The structural analysis of the new contents does not rely on the performance of the uranium fuel, but rather on the same aluminum fuel cladding (and cladding mechanical properties) used for the previously approved contents. The new contents do not introduce any new materials or mechanical properties that are credited for the contents' structural integrity under normal conditions of transport and accident conditions of transport.

Based on the evaluations above, the staff finds that the package continues to meet the requirements of Paragraph 614 of SSR-6, Rev. 1.

7.4 Aging Considerations

The application provides an aging evaluation in Section (II)-F to address the new requirements in the SSR-6, Rev. 1 to include aging mechanism considerations in the package design and operations. Aging causes considered in the evaluation include temperature changes, radiation generated from stored materials, chemical changes such as corrosion, and fatigue. The application specified that the evaluation considered a 40 year lifetime, with three transports a year. Materials considered in the evaluation include stainless steel, rigid polyurethane foam, and balsa wood. The rigid polyurethane foam (heat insulator) and balsa wood (shock absorber) are contained in the spaces between the outer and inner lids and between the inner and outer shells. The applicant concluded that aging would not affect the integrity of the package because (1) component temperatures are low [no more than 65°C (149°F)], (2) radiation exposures are insignificant with respect to the potential to alter material properties, (3) the passive nature of stainless steel, which encloses the other materials, ensures that corrosion will be insignificant, and (4) the allowable number of repetitions during the planned use period is greater than the expected number of repetitions. The applicant also cited the periodic inspections in its maintenance program as providing additional assurance that the stainless steel will be adequately maintained.

The staff confirmed that the evaluation properly considered the maximum temperature during transport, irradiation dose, and chemical factors. The staff notes that the low temperature and small radiation exposures are not considered to be capable of affecting the performance of the materials of package construction, which are commonly used in radioactive material transportation packages. In addition, although stainless steel can be subject to corrosion mechanisms in certain environments, the staff observes that regular inspections are conducted of the stainless steel to identify corrosion and cracks. The stainless steel encases the rigid polyurethane foam and balsa wood, which are moisture-sensitive materials, and keeps them in a closed space. These inspections will allow for prompt corrective maintenance of the stainless steel, in order to preserve this function of the stainless steel. Therefore, the staff finds the applicant's consideration of aging mechanisms to be acceptable.

Based on the evaluations above, the staff finds that the package meets the requirements of Paragraphs 613A and 809(f) of SSR-6, Rev. 1.

7.5 Conclusion

Based on a review of the statements and representations contained in the application, the staff concludes that the materials and their evaluations have been adequately described, and the Model No. JRF-90Y-950K package has adequate materials performance to meet the requirements of the IAEA SSR-6, Rev. 1.

8.0 OPERATING PROCEDURES

There were no changes to the operating procedures by the addition of the spectrum converter as authorized contents.

9.0 MAINTENANCE PROGRAM

There were no changes to the maintenance program by the addition of the spectrum converter as authorized contents.

CONCLUSION

Based on the statements and representations contained in the documents referenced above (see SUMMARY, above), the staff concludes that the Model No. JRF-90Y-950K package meets the requirements of International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material, IAEA Safety Standards Series, No. IAEA SSR-6, Rev. 1.

Issued with letter to R. Boyle, Department of Transportation,
Dated April 1, 2022