SAFETY EVALUATION REPORT
Docket No. 71-3036
Model No. JRF-90Y-850K
Japanese Certificate of Competent Authority J/170/B(U)F-96, Revision 3

SUMMARY

By letter dated October 1, 2020 (Agencywide Documents Access and Management System Accession No. ML21033A636), as supplemented on September 28, 2021 (ADAMS Accession No. ML21336A406), 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/170/B(U)F-96, Revision 3, dated June 23, 2020, 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 addition of the content described in Table 4 of the Japanese certificate, “Kyoto University Critical Assembly (KUCA) fresh fuel elements.”

The NRC reviewed the application, as supplemented, against the requirements in International Atomic Energy Agency (IAEA) Specific Safety Requirements, No. SSR-6, “Regulations for the Safe Transport of Radioactive Material,” (SSR-6), 2012 Edition.

In support of this request, the DOT provided the following documents for review with its letter dated November 6, 2019:

1. Japanese Certificate of Competent Authority J/2039/B(U)F, dated June 23, 2020,
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/170/B(U)F-96 for the subject 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) and on April 1, 2022 (ADAMS Accession No. ML22083A079). 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/170/B(U)F-96, 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.

1.2 Contents

The applicant requested approval of KUCA fresh fuel elements as authorized contents. The KUCA fresh fuel elements have two types: Coupon type and Flat type. Fuel dimensions and materials of construction for both types are provided in SAR figures D.20 and D.21. The coupon fuel is roughly 50 mm x 50 mm square and less than 3 mm thick, while the plate type fuel is 1.5 mm thick and measures 600 mm long by 62 mm wide. Both fuel types are encased in aluminum alloy (AG3NE) cladding, which has been used in other previously approved fuel types. The fuel cladding is treated as a containment boundary, in addition to the package's overall containment boundary.

2.0 STRUCTURAL EVALUATION

The objective of the structural evaluation is to demonstrate that the JRF-90Y-950K package has sufficient structural performance to meet the requirements of the IAEA SSR-6. The JRF-90Y-950K package was originally issued a DOT certificate of competent authority, with the requisite review and approval by NRC. In that application, the structural response of the package was evaluated through prototype testing and analytical evaluation. The package was subsequently revalidated by NRC on August 31, 2010, and on April 1, 2022.

The applicant proposed a change to include the KUCA fuel elements as additional contents. The NRC structural review focused on the impacts to the structural performance of the package as a result of this change.

2.1 KUCA Fuel Elements

The applicant evaluated the structural integrity of the two new fuel types using American Society of Mechanical Engineers (ASME) Section III, Division 1 Subsection NB, and following the previously approved methodology used to evaluate the other package contents. Specifically, the applicant evaluated buckling of the fuel under drop test conditions (normal and accident) for various package orientations using g-loads previously documented for each drop. The applicant appended existing tables with stress criteria and drop scenario for both new fuel types, along with calculated margins of safety for both new fuel types. All margins of safety were calculated to be above zero.

2.2 Evaluation Findings

Based on the review of the statements and representations contained in the application, as supplemented, the staff finds that the JRF-90Y-950K package has sufficient structural performance to meet the standards in IAEA SSR-6.

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, when evaluated for normal and accident conditions of transport as defined in the IAEA regulations. The JRF-90Y-950K package was originally issued a DOT certificate of competent authority, with the requisite review and approval by NRC. In that application, the thermal response of the package was evaluated through prototype testing and analytical evaluation. The package was subsequently revalidated by NRC on August 21, 2010.

The requested changes to include the KUCA fuel elements as additional contents do not have any impacts on the current thermal performance of the package.

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.

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.

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 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, 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. 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 for normal and accident conditions of transport.

5.0 SHIELDING EVALUATION

There were no changes to the shielding evaluation by the addition of the KUCA fuel elements as authorized contents.

6.0 CRITICALITY EVALUATION

NRC previously revalidated the CoC for this package in 2010 (ADAMS ML102440020). The only significant change to the package design in this application is the addition of KUCA fresh fuel elements as allowable contents.

The KUCA fresh fuel elements consist of two types: coupon fuel and flat fuel. The coupon fuel is a uranium-molybdenum-aluminum dispersion alloy with a maximum mass of 4,800 grams ^{235}U per package (4 grams ^{235}U per coupon fuel element). The flat fuel is a uranium-silicon-aluminum dispersion alloy with a maximum mass of 2,500 grams ^{235}U per package (15 grams ^{235}U per flat fuel element). Both fuel elements consist of uranium enriched to 19.95 weight percent ^{235}U.

Both the coupon and flat fuel elements consist of the fuel "meat" enclosed in an aluminum alloy cladding. Prior to loading into the package, fuel element plates are inserted into an aluminum sheet and wrapped by a buffer such as polyurethane foam for protection. Figures D.20 and D.21 of the application show the dimensions of the coupon and flat fuel elements, respectively. Fuel material properties important for the criticality model are shown in Table E.6 of the application. The package may contain up to 120 coupon elements or 30 flat fuel elements per basket location, for a total of 1,200 coupon fuel elements or 300 flat fuel elements per package.

The applicant modeled arrays of packages under accident conditions of transport, each containing KUCA fuel elements. 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. Since the KUCA fuel contents may contain low density plastic wrapping and silicone rubber spacers which potentially have a higher hydrogen density than water, the applicant performed a sensitivity study which demonstrates that the most reactive water density bounds any consideration of plastic or silicone materials within the contents. The applicant also considered fewer than the maximum number of fuel elements allowed, to determine if a higher moderator to fuel ratio was more reactive. The applicant determined that a lower number of flat fuel elements (280) was more reactive than the full number allowed (300), while the maximum number of coupon fuel elements (1,200) was most reactive.

The applicant modeled a triangular-pitched 6 x 5 x 2 array of 60 packages under accident conditions of transport, with the most reactive number of KUCA coupon or flat fuel elements in each basket location, optimally moderated by water and with the most reactive water density in between the packages, and fully reflected by water on the outside of the array. The applicant's resulting maximum system k_{eff} plus three times the calculation Monte Carlo uncertainty (3σ) is 0.8919, which is below the applicant's calculated Upper Subcritical Limit of 0.9200, based on the benchmarking analysis in the application. Since the applicant used the evaluation of package arrays under accident conditions of transport to bound arrays under normal conditions of transport, the applicant's array analysis supports a criticality safety index (CSI) of 4.2, when determined in accordance with IAEA SSR-6 paragraph 686 (5N = 60; 50/N = 4.167).

The staff reviewed the configurations modeled by the applicant for the package array analyses. The staff finds that the applicant has identified the most reactive credible condition of arrays of packages, 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 KUCA fuel elements, 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 did apply a bias value of 0.03 (resulting in a USL of 0.9200), which conservatively bounds the underestimation of k_{eff} shown in any of the experiments considered.

The applicant's benchmark analysis contained several deficiencies, when compared to 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 USL (>0.02 in k_{eff});

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 low-enriched uranium fuel plates in a package would be greater than the margin of subcriticality; and
3. the staff's independent analysis (discussed below), using a more modern version of SCALE with more modern cross section data, confirmed the applicant's calculated k_{eff} values.

The staff performed independent confirmatory analyses of the JRF-90Y-950K package using the CSAS6 sequence of the SCALE 6.2.3 code system, with KENO VI and the continuous-energy ENDF/B-VII.1 cross section library. The staff modeled arrays of packages using assumptions and modeling parameters similar to those used by the applicant. The staff's independent evaluation resulted in k_{eff} values that were similar to, or bounded by, the applicant's results.

6.1 Evaluation Findings

The staff reviewed the CoC 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.

7.0 MATERIALS EVALUATION

The purpose of the materials evaluation is to verify that the materials performance of the JRF-90Y-950K package meets the regulatory requirements of IAEA SSR-6. 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 KUCA fresh fuel elements as allowable package contents.

SAR Chapter(s) I-A (11), (I)-D, and (I)-Table A.1, (I)-Table D.1 and (I)-Table D.3 describe the new KUCA Square Plate Coupon (Uranium molybdenum aluminum dispersion alloy) and the Flat Plate (Uranium silicon aluminum dispersion alloy) fuel elements, both with the same aluminum alloy cladding that was used for previously approved fuel contents. The staff notes that the fuel plates are manufactured and inspected with the same process and controls that were previously approved for the JRF-90Y-950K.

7.1 Mechanical Properties of Package Materials

The staff notes that the fresh fuel contents do not introduce any material changes, as discussed in the paragraph above. Therefore, the mechanical properties used in the structural analysis of the added fuel elements support the prior finding that the applicant meets the requirements of Paragraph 639 of SSR-6.

7.2 Content Reactions

The staff notes that the additional fuel types 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 fuel under dry conditions, and atmospheric conditions surrounding the fuel 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 applicant continues to meet the requirements of Paragraph 614 of SSR-6.

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 and accident conditions.

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

7.5 Evaluation Findings

Based on a review of the statements and representations contained in the application, the staff concludes that the materials and evaluations have been adequately described, and the Model JRF-90Y-950K package has adequate materials performance to meet the requirements of IAEA SSR-6.

8.0 OPERATING PROCEDURES

There were no changes to the operating procedures by the addition of the KUCA fuel elements as authorized contents.

9.0 MAINTENANCE PROGRAM

There were no changes to the maintenance program by the addition of the KUCA fuel elements 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, 2012 Edition.

Issued with letter to R. Boyle, Department of Transportation, dated ____________.