May 7, 2019

Mr. Richard W. Boyle
Radioactive Materials Branch
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, D.C. 20590

SUBJECT: CERTIFICATE OF APPROVAL NO. CDN/2048/B(U)F FOR THE MODEL NO. F-257 (SERIAL NO. 2) PACKAGE

Dear Mr. Boyle:

This is in response to your letter dated September 26, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18277A040), requesting our assistance in evaluating the Model No. F-257 (Serial No. 2) transport package, authorized by Canadian Certificate of Approval No. CDN/2048/B(U)F, Revision 9.

Based upon our review, the statements and representations contained in the application, in the safety analysis report, "Evaluation of AECL-CP Shipping Flask Model F-257," and for the reasons stated in the enclosed safety evaluation report, we recommend revalidation of Canadian Certificate of Approval No. CDN/2048/B(U)F, Revision 9, for the Model No. F-257 (Serial No. 2) package, with the following additional conditions:

(A) Total Package Weight: 6,960 pounds

(B) Contents:

The Saskatchewan Research Council SLOWPOKE-2 Reactor core consistent with the following specifications:

Type, Form, and Maximum Quantity of Material per Package

Type of Nuclear Reactor Assemblies:	SLOWPOKE – 2
Fuel Element Type:	Pin
Maximum mass of assembly	5048.9 grams
Maximum number of fuel elements per package:	297 fuel pins
Maximum fuel element length:	23.56 cm
Maximum fuel element outer diameter:	0.61 cm
Maximum decay heat per package:	0.987 watt
Maximum initial enrichment, weight percent U-235:	93.18%
Maximum initial mass, U-235:	830.12 grams
Maximum initial mass, Uranium:	891 grams
Maximum burnup Kwh / fuel core:	220,230
Minimum cooling time:	14 days

(C) Minimum Transport Index for Criticality Control: 100

(D) Periodic Leakage Test:

Completion of a periodic leakage test in accordance with ANSI N14.5, to verify a leakage rate not to exceed 1 X 10^{-7} std-cm^3/s within one year prior to shipment.

If you have any questions regarding this matter, please contact me or Chris Allen of my staff at (301) 415-6877.

Sincerely,

/RA Bernie White Acting for/

John McKirgan, Branch Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-3054
EPID L-2018-NEW-0008

Enclosure:
Safety Evaluation Report

SUBJECT: CERTIFICATE OF APPROVAL NO. CDN/2048/B(U)F FOR THE MODEL NO. F-257 (SERIAL NO. 2) PACKAGE, DOCUMENT DATE: May 7, 2019

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ADAMS Accession No.: ML19128A003

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SAFETY EVALUATION REPORT
Docket No. 71-3054
Model No. F-257 Package (Serial No. 2)
Certificate of Approval No. CDN/2048/B(U)F
Revision 9

SUMMARY

By letter dated September 26, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18277A040), the U.S. Department of Transportation (DOT) requested review and recommendation regarding revalidation of Canadian Certificate of Approval No. CDN/2048/B(U)F, Revision 9, for the Model No. F-257 (Serial No. 2) package. DOT provided the following documents with its letter dated September 26, 2018:

1. Canadian Competent Authority Certificate of Approval No. CDN/2048/B(U)F, Revision 9, dated July 29, 2016.
2. United States Department of Energy Spent Nuclear Fuel Acceptance Criteria, dated August 26, 2018.

The NRC previously reviewed and recommended revalidation of this package to the DOT on three different occasions. Each time, the package contained SLOWPOKE-2 research reactor cores with slightly different characteristics. The first recommendation of revalidation to the DOT was by letter dated March 29, 2000 (ADAMS Accession No. ML003698735). The second recommendation of revalidation to the DOT was by letter dated February 14, 2011 (ADAMS Accession No. ML110450346). The third recommendation of revalidation to the DOT was by letter dated January 12, 2017 (ADAMS Accession No. ML17012A170). Staff used the previous safety findings in those reviews, in addition to the application material provided by the DOT, to evaluate their recommendation for this revalidation request. Based on the statements and representations in the information provided by DOT and AECL, the staff recommends that Certificate of Approval No. CDN/2048/B(U)F, Revision 9, dated July 29, 2016, be revalidated for the contents listed below (see Contents).

1.0 GENERAL INFORMATION

1.1 Package Description

Information provided by the applicant showed that the packaging consists of an inner container (flask) and an impact limiting fire shield overpack. The inner container consisted of a lead cylinder, encased in stainless steel, with a removable top plug attached by eight 5/8-inch diameter bolts. A silicone O-ring within the removable top plug sealed the inner container. The overpack, which had overall dimensions of approximately 60-inches high by 49.5-inches diameter, consisted of a capped, double carbon-steel wall cylinder mounted on a disk base. External fins welded to the outer skin transferred heat to the environment and provided impact energy absorption. Lifting lugs, integral to the design of four of the external fins, provided the capability to lift the package. Eight 1-inch diameter bolts attached the cylinder to the base disk. Information provided by the applicant also showed that the inner container is mounted to the overpack disk by four steel brackets and eight 3/4-inch diameter bolts.

1.2 Contents

Transport of the Saskatchewan Research Council (SRC) SLOWPOKE-2 Reactor core is authorized, consistent with the following specifications:

(A) Total Package Weight: 6,960 pounds

(B) Contents:

The SRC SLOWPOKE-2 Reactor core consistent with the following specifications:

Type, Form, and Maximum Quantity of Material per Package

Type of Nuclear Reactor Assemblies:	SLOWPOKE – 2
Fuel Element Type:	Pin
Maximum mass of assembly	5048.9 grams
Maximum number of fuel elements per package:	297 fuel pins
Maximum fuel element length:	23.56 cm
Maximum fuel element outer diameter:	0.61 cm
Maximum decay heat per package:	0.987 watt
Maximum initial enrichment, weight percent U-235:	93.18%
Maximum initial mass, U-235:	830.12 grams
Maximum initial mass, Uranium:	891 grams
Maximum burnup Kwh / fuel core:	220,230
Minimum cooling time:	14 days

(C) Minimum Transport Index for Criticality Control: 100

(D) Periodic Leakage Test:

Completion of a periodic leakage test in accordance with ANSI N14.5, to verify a leakage rate not to exceed 1 X 10^{-7} std-cm^3/s within one year prior to shipment.

3.0 THERMAL

The applicant requested, by letter dated September 28, 2018, that the SRC SLOWPOKE-2 Reactor core be added as authorized contents to the Model No. F-257 package. Information submitted by the applicant identified that the package is loaded with only one assembly and the maximum decay heat is 0.987 watts. The applicant also confirmed that the F-257 safety analysis report, “Evaluation of AECL-CP Shipping Flask Model F-257” (Rev. 1), which was submitted for a previous application, was still applicable for this request.

The staff reviewed the application and determined that the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) thermal analyses, which were previously reviewed and approved by the NRC, are still valid for this application. The staff also determined that the heat removal capability of the Model No. F-257 package is acceptable because the package configuration remains unchanged and because the maximum heat load requested by this revalidation is less than what was previously approved (i.e., one watt).

The staff finds that the Model No. F-257 package, loaded with the SRC SLOWPOKE-2 Reactor core, will not have fuel and packaging component temperatures exceeding the allowable NCT

and HAC limits and will not result in over-pressurization due to its low heat load limit of 0.987 watts. The staff reviewed the package design, contents, and preparations for shipment and concludes that the Model No. F-257 package, loaded with SRC SLOWPOKE-2 Reactor core, meets the thermal requirements of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended).

5.0 SHIELDING

The applicant requested revalidation of the Model No. F-257 package Competent Authority Certificate to transport the SRC SLOWPOKE-2 Reactor core, a light water moderator 20-kW pool type reactor, which consists of 297 fuel pins at 93% enriched uranium containing 830 g U-235. The applicant provided the following reactor operation information:

(1) the reactor operated for 97,929 flux-hours at the equivalent thermal neutron flux of 1×10^{11} n/cm^2/s as of April 2018,
(2) the reactor is expected to run for another 3230 hours at the same equivalent thermal neutron flux from May 2018 until April 2019,
(3) the reactor will run at 5% of 1×10^{11} n/cm^2/s neutron flux for approximately 5 hours prior to removing the core from the reactor, and
(4) the reactor operational period will run for a total of 101,160 flux-hours at a neutron flux of 1×10^{11} n /cm^2/s before the core is removed.

Based upon this information, the core burnup equated to 220,230 kWh.

Staff evaluated the package in accordance with the requirements of both paragraphs 532 and 534 of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended) which require that the package be shipped in an exclusive use closed vehicle if either the surface dose rate exceeds 200 mrem/hr, or if the transport index exceeds 10. For exclusive use shipments, the regulations allow a dose rate of up to 1000 mrem/hr at the package surface.

The staff previously approved the F-257 package for transport of the Dalhousie University SLOWPOKE-2 Reactor (DUSR) fuel core and University of Toronto SLOWPOKE-2 fuel core The DUSR fuel core contained 822 g U-235, had an initial enrichment of 93 weight percent U-235 and had a total burnup of 313,060 kWh over 23 years with the reactor operating for approximately 40,000 hours. The University of Toronto SLOWPOKE-2 fuel core contained 825 g U-235, had an initial enrichment of 93 weight percent U-235 and had an irradiation history of 5 kW for 23 years for a total burnup of 297,208 KWh. The burnup of the DUSR fuel core and the University of Toronto fuel core exceeded the SRC SLOWPOKE-2 Reactor core burnup by factors of 1.55 and 1.46 respectively. As part of its confirmatory review, the staff independently evaluated the source terms for and the shielding capabilities of the F-257 package containing the design basis SLOWPOKE-2 fuel in the previous applications using the SAS2H and SAS4 modules, respectively, of the SCALE 4.4 computer code. The staff's results agreed well with the values in Appendix II of Evaluation of AECL-CP Shipping Flask Model F-257.

The shielding evaluation in Appendix II of Evaluation of AECL-CP Shipping Flask Model F-257 presented dose rates generated from shielding curves for mixed fission products. The SLOWPOKE-2 fuel design basis parameters assumed a total core loading of 830 g U-235, 300 fuel pins, and an irradiation history of 2 kW for 5 years followed by 20 kW for 10 hours, an initial enrichment of 93 weight percent, and a minimum cooling time of 1 day. Staff reviewed Table II-A in Appendix II of AECL-CP Shipping Flask Model F-257 which contained the following maximum external dose rates for the F-257 package (including the crush/fireshield) during NCT:

Location Dose Rate	Contact (mrem/hr)	1 meter (mrem/hr)
Side	69	10.5
Top	2.4	0.4
Bottom	30	3.2

The package was subjected to the HAC tests in accordance with the requirements of Safety Series 6, 1973 Revised Edition (As Amended), paragraphs 719 and 720. Although portions of the crush/fireshield were crushed following the testing, the crush/fireshield remained in place. In addition, although the flask itself remained intact, some lead slump occurred at the bottom of the package. A radiation shielding test, documented in Appendix VI of Evaluation of AECL-CP Shipping Flask Model F-257, demonstrated that dose rates outside the package following accident conditions are higher than the normal condition dose rates but still well below the limits of paragraph 537 of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended). Information provided by the applicant demonstrated that the SRC SLOWPOKE-2 Reactor core is bounded by the design basis source term in Appendix II of Evaluation of AECL-CP Shipping Flask Model F-257.

The staff independently calculated a source term for the SRC SLOWPOKE-2 Reactor core fuel using SCALE 6.1. The staff concluded that the SRC SLOWPOKE-2 Reactor core fuel is bounded by the design basis fuel based on the SCALE 6.1 source term results. Furthermore, the staff performed a Monte Carlo shielding evaluation of the package with the SRC SLOWPOKE-2 Reactor core fuel and found that the calculated dose rates around the package are well below those presented in Appendix II of Evaluation of AECL-CP Shipping Flask Model F-257.

The staff concludes that the shielding analyses demonstrate that the external dose rates for the F-257 package, containing the SRC SLOWPOKE-2 Reactor core with a total reactor operating history of approximately 101,160 flux-hours, meets the limits in the IAEA Safety Series No. 6, 1973 Revised Edition (As Amended).

6.0 CRITICALITY

The objective of the staff's review is to determine if the Model No. F-257 package still meets the IAEA Safety Series No. 6, 1973 Revised Edition (As Amended) requirements when loaded with a SRC SLOWPOKE-2 Reactor core consisting of 297 fuel pins enriched to a maximum of 93.19 wt.% U-235. Staff previously reviewed both supplemental criticality analyses provided by the applicant, which evaluated a single package under both NCT and HAC, and Evaluation of AECL-CP Shipping Flask Model F-257, Revision 1. The staff limited the scope of its review to evaluate compliance with the criticality safety requirements of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended), paragraphs 615-619.

Criticality analyses in Evaluation of AECL-CP Shipping Flask Model F-257, Revision 1 assumed an "allowable number" of one package under the IAEA Class-II fissile requirements. Previously, staff found the supplemental criticality analysis acceptably showed the Model No. F-257 package will remain subcritical by modeling 8 packages in a 2x2x2 array under NCT and 2 packages under HAC. The number or packages analyzed by the applicant meets the requirements of paragraph 619.

Using information provided by the applicant, staff developed a model of fully reflected and moderated fuel pins in a hexagonal array in water with the SRC SLOWPOKE-2 Reactor fuel characteristics. The previously reviewed supplemental criticality analysis evaluated a full SLOWPOKE-2 reactor core consisting of 342 fuel pins with an initial enrichment of 93.5 wt.% U-235 containing 957.6 grams of U-235. The current SRC SLOWPOKE-2 Reactor core for which the applicant requested authorization contained 297 fuel pins, had an initial enrichment of 93.19 wt.% U-235 and contained a maximum of 831.16 grams of U-235. Staff selected cases to correspond with the applicant's prior determination of optimum pitch in an updated criticality analysis in addition to corresponding homogenized cases. Staff confirmatory analyses consisted of cases where pins were removed in groups of adjacent lattice locations as well as distributed single lattice locations. Staff's analysis also included cases that varied the lattice pitch. Staff compared the reactivity of the selected cases and confirmed that all cases with the same geometry are less reactive with lower fissile mass (i.e., fewer fuel rods). For this reason, staff finds that the SRC SLOWPOKE-2 Reactor core is bounded by previous staff reviews of the Model No. F-257 package.

The Model No. F-257 package is to be used for the transport of the SRC SLOWPOKE-2 Reactor core. The contents of the current SRC SLOWPOKE-2 Reactor core are bounded by a previously approved supplemental criticality analysis. Therefore, as demonstrated by the previous revalidation in 2000 and staff's own analysis, the staff concludes that the SRC core can be safety transported in adherence to the requirements of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended).

CONCLUSION

Based on the statements and representations contained in the documents referenced above (see SUMMARY), and the conditions listed above (see Contents), the staff concludes that the Model No. F-257 (Serial No. 2) package meets the requirements of IAEA Safety Series No. 6, 1973 Revised Edition (As Amended).

Issued with letter to R. Boyle, Department of Transportation,
on May 7, 2019.