SAFETY EVALUATION REPORT
Docket No. 71-3043
Model No. MFC-1
Japanese Package Design Certificate No. J/105/AF-96
Revision 2

SUMMARY

The Department of Transportation (DOT) requested NRC's recommendation concerning the revalidation of the Model No. MFC-1 package, Japanese Package Design Certificate No. J/105/AF-96, Rev. 2. The package is currently licensed under International Atomic Energy Agency (IAEA) *Regulations for Safe Transport of Radioactive Material*, TS-R-1, Rev. 2005, by the Japanese Competent authority. The package is designed to transport unirradiated Pressurized Water Reactor (PWR) fuel assemblies. The PWR fuel is fabricated from either uranium dioxide (UO_2) pellets or Gadolinia UO_2 pellets. The allowable Uranium-235 enrichment in the fuel assemblies is five weight percent or less. The package is suitable for both sea and road transport.

Based on the statements and representations in the application, as supplemented, the NRC recommends revalidation of the Japanese Package Design Certificate No. J/105/AF-96, Rev. 2, for use in the United States, with the following conditions:

(1) packages must be fabricated in accordance with Figures III-A-1, -4, -6, and -7 in Appendix III and Table 1-C.1 in Section 1 of the Safety Analysis Report;
(2) the package contents are limited to those specified in the Japanese Competent Authority Certificate; and
(3) transport by air is prohibited.

1.0 GENERAL INFORMATION

1.1. Packaging

Engineering drawings are provided in the Safety Analysis Report (SAR). A description of the contents is provided in the SAR and coincides with the contents approved on the Japanese Package Design Certificate No. J/105/AF-96, Rev. 2. The contents allowed by the Japanese certificate are PWR fuel assemblies fabricated either from UO_2 or Gadolinia UO_2. The allowable Uranium-235 enrichment in the fuel assemblies is five weight percent or less.

A description of the packaging is provided and consists of a main body, lifting trunnions, lid and bottom plug, shock absorber, and seals. The fuel assembly rods provide containment of the radioactive material transported. Therefore, the MFC-1 package does not utilize a containment system.

1.2. Findings

Based on review of the statements and representations in the application, the staff concludes the design has been adequately described and evaluated to meet the International Atomic Energy Agency (IAEA) requirements of TS-R-1, Rev. 2005. The TS-R-1 regulations relevant to this package with respect to general information are listed in Section 1.3.

1.3. IAEA Regulations Applicable to General Information Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
813	An application for approval shall include all information necessary to satisfy the competent authority that the design meets the requirements of para. 671 and a specification of the applicable quality assurance program as required in para. 310.	Requirement met. The staff reviewed the application, as supplemented, and believes that the requirements of paragraph 671 are met and that the applicant's quality assurance program is satisfactory.

2.0 STRUCTURAL EVALUATION

2.1. Packaging

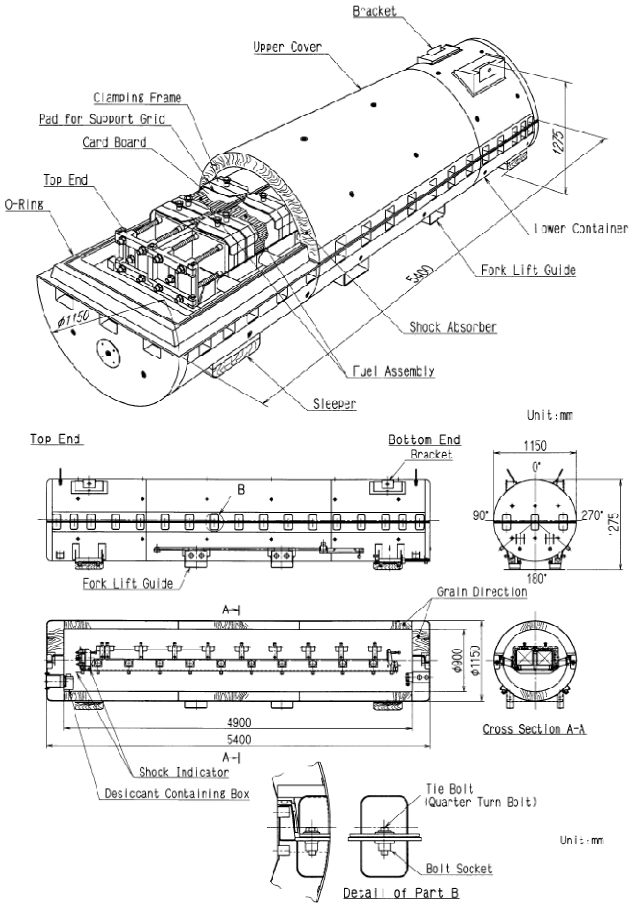
The MFC-1 has the following nominal outside dimensions: an overall length of 5400 mm, an outside diameter of 1150 mm and a height of 1275 mm. The total mass of the package is 4320 kg (2804 kg packaging plus 2 fuel assemblies).

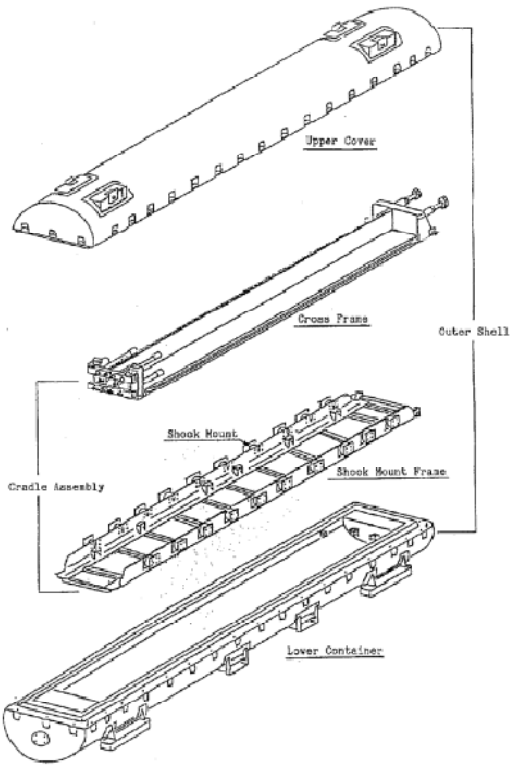
The MFC-1 package consists of an outer shell (comprised of an upper cover and a lower container) and a cradle assembly (comprised of a shock mount frame, mounts, and auxiliary devices). A maximum of two fuel assemblies will be contained and transported in a horizontal position.

The outer shell consists of an upper cover and a lower container. The outer shell is a cylindrical, watertight structure, and its outer surface is so structured that rainfall is difficult to accumulate on the package. Brackets are attached to the upper cover at four positions for lifting the package during transportation. Wood (acting as both heat insulator and shock absorber) fills the space between the external cylinder and internal cylinder. A neoprene o-ring acts as a seal to prevent water from entering the package internals during Normal Conditions of Transport (NCT).

The cross frame can carry two fuel assemblies. Rubber cushions on the contact surface between the cross frame and fuel assemblies increase the cushioning effect. Boron stainless steels plates act as a neutron absorber and are attached on the entire surface of the cross frame. Clamping frames fix the support grids of fuel assemblies and the top nozzle during transport. The shock mount frame is mounted inside the packaging through the shock mounts.

There are no components that act as a containment device in the MFC-1 packaging. The containment boundary consists of the fuel cladding and the end plugs of the fuel rod.





Two full scale prototypes were used to test the packaging and containment boundary under the strength test [paras. 727(a) and (b)] and thermal test conditions (para. 728). The two prototype packages were very similar in mass and exact in dimension and material specifications to the actual MFC-1 packaging (SAR Table II-F.3). Dummy fuel assemblies with the same dimensional features as those of the 15x15 (12 feet) fuel assemblies, and similar weight of the 17x17 (12 feet) assemblies, were used in the prototypes. The prototype tests are documented in Section II-F of the SAR. The 9 m drop test was conducted in four different orientations on one prototype. The 1 m drop test onto a puncture bar test was conducted in eight different orientations on one prototype.

The impact response analysis code SHOCK was used for evaluation of the MFC-1 package for drop heights from the 1.2 m and 9 m heights. SHOCK was benchmarked by comparing the 9 m prototype results with the code results. SAR Section II-A, A.10.5

documents the analysis of the 1.2 m and 9 m free drop. Both the acceleration and deformation values calculated by SHOCK were higher than the experimentally determined values (SAR Table II-A.10) which indicates the analytical values have a margin of safety.

2.2. Structural Summary

The summary of damages received by this package under accident conditions of transport are described below.

1. 9 m Drop test
   The total deformation amount of the external cylinder of the container at the time of drop was 29 mm (horizontal drop) up to 198 mm (corner drop). These deformations do not reach the cradle assembly in any drop orientation. The impact accelerations and stresses generated during the 9 m drop tests are below the material allowables for the fuel rod (containment boundary) which indicates the fuel rods maintain their structural integrity and containment properties.

2. 1 m Drop test onto puncture bar
   The total deformation amount of the external cylinder of the container at the time of drop was 21 mm up to 104 mm (depending on orientation). The impact accelerations, and stresses generated, during the drop tests are below the material allowables for the fuel rod (containment boundary) which indicates the fuel rods maintain their structural integrity and containment properties.

The test results from the tested prototypes listed in SAR Section 5.4 confirm that the accident conditions onto the prototype were conclusive using SHOCK. The dummy fuel rod was confirmed by helium leak test to ensure that there were no cracks, fractures, etc., and the containment boundary was maintained.

The summary of damages received by the MFC-1 package under the NCT is described by each test item.

1. 1.2 m Drop test
   The deformation amount of the external cylinder of the container during the 1.2 m drop is 9.5 mm (horizontal case) up to 71 mm (corner drop). The impact accelerations and stresses generated during the 1.2 m drop tests are below the material allowables for the fuel rod (containment boundary) which indicates the fuel rods maintain their structural integrity and containment properties.

2. Other NCT tests
   The strength and containment of the fuel rod cladding is maintained during the free drop, pressure, vibration, water spray, and stacking tests which are part of the normal conditions of transport. The stresses generated during the tests are below the material allowables for the fuel rod (containment boundary) which indicates the fuel rods maintain their structural integrity and containment properties.

2.3. Structural Findings

The MFC-1 package and its authorized contents, restricted to unirradiated PWR fuel assemblies as described in the SAR, complies with the IAEA regulatory criteria for a Type A package with fissile content. The TS-R-1 regulations relevant to the structural evaluation of this package are listed in Section 2.4.

2.4. IAEA Regulations Applicable to Structural Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
606	*Package* mass, volume and shape shall be such that it can be easily and safely transported. In addition, the *package* needs to be properly secured in or on the *conveyance* during transport.	Requirement met. SAR section I-A (11)
607	Any lifting attachments on the *package* will not fail when used in the intended manner and that, if failure of the attachments should occur, the ability of the *package* to meet other requirements of these Regulations would not be impaired. Take account of appropriate safety factors to cover snatch lifting.	Requirement met. SAR II-A, para. A.4.4
608	Attachments and any other features on the outer surface of the *package* which could be used to lift it, shall be designed either to support its mass in accordance with the requirements of Para. 607 or shall be removable or otherwise rendered incapable of being used during transport.	N/A
609	As far as practicable, the *packaging* shall be so designed and finished that the external surfaces are free from protruding features and can be easily decontaminated.	Requirement met. See SAR II, para. 1(A)(c)
610	As far as practicable, the outer layer of the *package* shall be so designed as to prevent the collection and the retention of water.	Requirement met. Outer enclosure of the packaging is cylindrical.
612	The *package* shall withstand the effects of any acceleration, vibration or vibration resonance which may arise under routine conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the *package* as a whole. In particular, nuts, bolts and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.	Requirement met. SAR II-A, para. A.4.7
613	The materials of the *packaging* and any components or structures shall be physically and chemically compatible with each other and with the *radioactive contents*. Account shall be taken of their behavior under irradiation.	Requirement met. SAR II-A, para. A.4.1

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
614	All valves through which the *radioactive contents* could otherwise escape shall be protected against unauthorized operation.	Requirement met. The valve is protected by a cover prohibiting an unauthorized manipulation. See SAR I-C para. C-2-4.
615	The design of the *package* shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport.	Requirement met. See SAR II-B and II-C.
617	For *packages* to be transported by air, the temperature of the accessible surfaces shall not exceed 50°C at an ambient temperature of 38°C, with no account taken for insolation.	N/A
618	*Packages* to be transported by air shall be so designed that, if they were exposed to ambient temperatures ranging from –40°C to +55°C, the integrity of containment would not be impaired.	N/A
619	*Packages* containing *radioactive material*, to be transported by air, shall be capable of withstanding, without leakage, an internal pressure that produces a pressure differential of not less than the *maximum normal operating pressure* plus 95 kPa.	N/A
629 thru 632	Applicable to Fissile UF_6 only. For Details see TS-R-1	N/A
633	Type A packages shall be designed to meet the requirements specified in paras. 606–616 and, in addition, the requirements of paras. 617–619 if carried by air, and of paras. 634–649.	Requirement met - as applicable. See SAR.
634	The smallest overall external dimension of the package shall not be less than10 cm.	Requirement met. Smallest dimension is 1275 mm. See SAR I-A (7)
635	The outside of the package shall incorporate a feature such as a seal, which is not readily breakable and which, while intact, will be evidence that it has not been opened.	Requirement met. Security seals are provided. See SAR II-A A.4.3
636	Any tie-down attachments on the package shall be so designed that, under normal and accident conditions of transport, the forces in those attachments shall not impair the ability of the package to meet the requirements of these Regulations.	Requirement met. SAR II-A, para. A.4.5
637	The design of the package shall take into account temperatures ranging from –40°C to +70°C for the components of the packaging. Attention shall be given to freezing temperatures for liquids and to the potential degradation of packaging materials within the given temperature range.	Design temperature was -20C to 80C per II-A A.3
638	The design and manufacturing techniques shall be in accordance with national or international standards, or other requirements, acceptable to the competent authority.	Requirement met. See SAR III-A.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
639	The design shall include a containment system securely closed by a positive fastening device which cannot be opened unintentionally or by a pressure which may arise within the package.	Requirement met. Security seals are provided. See SAR II-A A4.3
640	Special form radioactive material may be considered as a component of the containment system.	N/A
641	If the containment system forms a separate unit of the package, it shall be capable of being securely closed by a positive fastening device which is independent of any other part of the packaging.	Requirement met by rod cladding.
642	The design of any component of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.	As each fuel rod has cladding, do not contain liquid, and has only UO2 pellets and inert gas, the requirement is met. See SAR II-C C.2.1.
643	The containment system shall retain its radioactive contents under a reduction of ambient pressure to 60 kPa.	Requirement met. See SAR II (1)(A)(j).
644	All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve.	Requirement met. The valve is protected by a cover prohibiting an unauthorized manipulation. See SAR I-C para. C-2-4.
645	A radiation shield which encloses a component of the package specified as a part of the containment system shall be so designed as to prevent the unintentional release of that component from the shield. For details see TS-R-1	Requirement met. See SAR I-C C.2.2 and II-A A.4.3
646	A package shall be so designed that if it were subjected to the tests specified in paras. 719–724, it would prevent: (a) Loss or dispersal of the radioactive contents; and (b) Loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the package.	Requirement met. See SAR II-A A.5
647	The design of a package intended for liquid radioactive material shall make provision for ullage to accommodate variations in the temperature of the contents, dynamic effects and filling dynamics.	N/A
648~670	Requirements for packages containing Fissile Material – as applicable	N/A – Package is Type A, fresh fuel
671~682	Requirements for packages containing Fissile Material – as applicable	Requirement met. See SAR
675	Geometry and temperature requirements: The packaging, after being subject to the tests specified in paras. 719-724, must prevent the entry of a 10 cm cube.	Requirement met. See SAR II-A A.5.7
676	A package for fissile material shall be designed for an ambient temp. range of -40 degrees C to +38 degrees.	Design temperature was -20C to 80C per II-A A.3

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
677,678, 679	The package shall be subcritical under the conditions of paras. 677 and 678 with the package conditions that result in the maximum neutron multiplication consistent with: (a) routine conditions of transport (incident free); (b) the tests specified in para. 681(b); and (c), the test specified in para. 682(b)	Requirement met. See SAR II-E E.4.4
701	Demonstration of compliance with the performance standards required in Section VI shall be accomplished by any of the methods listed below or by a combination thereof. For details see TS-R-1.	Requirement met. See SAR II-A A.5 and A.9
702	After the specimen, prototype or sample has been subjected to the tests appropriate methods of assessment shall be used to ensure that the requirements of this section have been fulfilled in compliance with the performance and acceptance standards prescribed in Section VI.	Requirement met. See SAR II-A A.5.7 and A.9.2.5
704	Specimens that comprise or simulate special form radioactive material shall be subjected to the impact test, the percussion test, the bending test, and the heat test specified in paras 705–709. A different specimen may be used for each of the tests. For further details see TS-R-1.	N/A – not special form
705	Impact test: The specimen shall drop onto the target from a height of 9 m. The target shall be as defined in para. 717.	N/A
706	Percussion test: For details see TS-R-1	N/A
707	Bending test: The test shall apply only to long, slender sources with both a minimum length of 10 cm and a length to minimum width ratio of not less than 10. For details see TS-R-1	N/A
708	Heat test: The specimen shall be heated in air to a temperature of 800°C and held at that temperature for a period of 10 minutes and shall then be allowed to cool.	N/A
709	Specimens that comprise or simulate radioactive material enclosed in a sealed capsule may be excepted from: see TS-R-1 for details	N/A
713	All specimens shall be inspected before testing in order to identify and record faults or damage including the following: (a) divergence from the design; (b) defects in manufacture; (c) corrosion or other deterioration; and (d) distortion of features.	Requirements met. See SAR II-F 4.1
714	The containment system of the package shall be clearly specified.	Requirements met. See SAR II-C C.2
715	The external features of the specimen shall be clearly identified so that reference may be made simply and clearly, to any part of such specimen.	Requirement met. Only 2 specimens.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
716	After each of the applicable tests specified in paras. 718–737: (a) Faults and damage shall be identified and recorded; (b) It shall be determined whether the integrity of the containment system and shielding has been retained to the extent required in Section VI for the package under test; and (c) For packages containing fissile material, it shall be determined whether the assumptions and conditions used in the assessments required by paras. 671–682 for one or more packages are valid.	Requirement met. See SAR II-A A.5 and A.9
717	The target for the drop test specified in paras. 705, 722, 725(a), 727 and 735 shall be a flat, horizontal surface of such a character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase damage to the specimen.	Requirements met. See SAR II-F 4.2.1(1)
718	Specimens that comprise or simulate packaging designed to contain 0.1 kg or more of uranium hexafluoride shall be tested hydraulically at an internal pressure of at least 1.38 MPa but, when the test pressure is less than 2.76 MPa, the design shall require multilateral approval. For retesting packaging, any other equivalent nondestructive testing may be applied subject to multilateral approval.	N/A
719	The tests are: the water spray test, the free drop test, the stacking test and the penetration test. Specimens of the package shall be subjected to the free drop test, the stacking test and the penetration test, preceded in each case by the water spray test. One specimen may be used for all the tests, provided that the requirements of para. 720 are fulfilled.	Requirements met. See SAR II-A A.5
720	The time interval between the conclusion of the water spray test and the succeeding test: For details see TS-R-1.	N/A as outer enclosure of the packaging is cylindrical.
721	Water spray test: The specimen shall be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm per hour for at least one hour.	N/A as outer enclosure of the packaging is cylindrical.
722 (a), (b), (c)	Free drop test: The specimen shall drop onto the target so as to suffer maximum damage in respect of the safety features to be tested. For details see TS-R-1.	Requirements met. See SAR II-A A.5.3
723	Stacking test: For details see TS-R-1.	Requirements met. See SAR II-A A.5.4
724	Penetration test: For details see TS-R-1.	Requirements met. See SAR II-A A.5.5
725	Additional tests for Type A packages designed for liquids and gases: (a) Free drop test, (b) Penetration test: For details see TS-R-1.	N/A

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
726	The specimen shall be subjected to the cumulative effects of the tests specified in para. 727 and para. 728, in that order. Following these tests, either this specimen or a separate specimen shall be subjected to the effect(s) of the water immersion test(s) as specified in para. 729 and, if applicable, para. 730.	Requirements met. See SAR II-A A.9.2
727	Mechanical test: The mechanical test consists of three different drop tests. Each specimen shall be subjected to the applicable drops as specified in para. 656 or para. 682. For details of Drop I, II, and III see TS-R-1.	Requirements met. See SAR II-A, A.9.2.1 and A.9.2.2. No test (c) per TS-R-1 para. 656 (b)(i)
728	Thermal test: For details of the thermal test see TS-R-1.	Requirements met. See SAR II-A A.9.2.3
729	Water immersion test: The specimen shall be immersed under a head of water of at least 15 m for a period of not less than eight hours in the attitude which will lead to maximum damage. For demonstration purposes, an external gauge pressure of at least 150 kPa shall be considered to meet these conditions.	Requirements met. See SAR II-A A.9.2.4
730	Enhanced water immersion test for Type B(U) and Type B(M) packages containing more than 105 A2 and Type C packages: Enhanced water immersion test: The specimen shall be immersed under a head of water of at least 200 m for a period of not less than one hour. For demonstration purposes, an external gauge pressure of at least 2 MPa shall be considered to meet these conditions.	N/A
731	Water leakage test for packages containing fissile material. For details see TS-R-1.	Exempt - See SAR II-E E.4.2 and E.4.4
732	Water leakage test for packages containing fissile material. For details see TS-R-1.	Requirements met. See SAR II-A A.9.2
733	Water leakage test for packages containing fissile material. For details see TS-R-1	Requirements met. See SAR II-A A.9.2.4
734	Specimens shall be subjected to the effects of each of the following test sequences in the orders specified: (a) the tests specified in paras. 727(a), 727(c), 735 and 736; and (b) the test specified in para. 737. Separate specimens are allowed to be used for each of the sequences (a) and (b).	N/A
735	Puncture/tearing test: The specimen shall be subjected to the damaging effects of a solid probe made of mild steel. The orientation of the probe to the surface of the specimen shall be such as to cause maximum damage at the conclusion of the test sequence specified in Para. 734(a). See TS-R-1 for details.	N/A

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
737	Impact test: The specimen shall be subject to an impact on a target at a velocity of not less than 90 m/s, at such an orientation as to suffer maximum damage. The target shall be as defined in para. 717, except that the target surface may be at any orientation as long as the surface is normal to the specimen path.	N/A

2.5. Materials Evaluation

A materials review for revalidation of the MFC-1 package was conducted as indicated in the enclosed table. In particular, requirements dealing with the compatibility of the materials, ability of the materials to perform without generating gases, or corrosive atmospheres due to corrosion or radiolysis and ability of the materials to meet the temperature requirements were evaluated in detail. This package contains no pyrophoric, flammable, or explosive components. In addition the thermal and mechanical properties of the contents and materials of construction were checked to ensure that requirements in paragraph 646(b) could be met. The SAR specifies that a QA manual will be produced that includes all the standards for design, materials, and construction.

2.6. Materials Findings

The staff believes that all the materials TS-R-1 regulations applicable to a Type A package listed in Section 2.7 are met as limited by the conditions listed in the letter.

2.7. IAEA Regulations Applicable to Materials Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
507	Sets the requirements of other dangerous properties of the package contents, such as explosiveness, flammability, pyrophoricity, chemical toxicity and corrosiveness that should be taken into account in the packing, labeling, marking, placarding, storage and transport in order to be in compliance with the transport regulations for dangerous goods of each of the countries through or into which the materials will be transported, and, where applicable, with the regulations of the cognizant transport organizations, as well as these Regulations.	The staff finds that this package or its fresh fuel contents contains no explosive, chemically toxic, or corrosive substances. The only flammable material is the balsa wood used as a shock absorber outside the package. In the form of fuel rods, the Zircaloy fuel rods are not pyrophoric. The only chemically toxic material is the Cd in the control rod absorber alloy where it is not available for interaction or release. The staff finds this requirement is met.
607	Specifies that the design shall be such that any lifting attachment on the package will not fall when used in the intended manner and that, if failure of the attachments should occur, the ability of the package to meet other requirements of these Regulations would not be impaired. The design shall take account of appropriate safety factors to cover snatch lifting.	Not applicable - This package has no trunnions

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
613	States that the materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behavior under irradiation.	The package is constructed of steels, balsa wood, neoprene, and ethylene propylene. The contents are fresh fuel assemblies containing Zircaloy clad fuel rods and assembly components of steel and inconel. The staff is aware that hydrogen and fluorine (neoprene) generation are only possible, in the polymer materials, only if the gamma field is well above what is experienced in a fresh fuel package. Therefore these gases will not be generated. SAR Table II-A.10 lists the various dissimilar components in contact with each other. They are all stable in air and compatible with each other. The staff agrees with the conclusion in the SAR that there are no chemical or galvanic interactions will occur. During sea transport, the entrance of water is precluded by the neoprene seals (SAR Section II-B.3). During normal transport, the moisture in the container is removed by the use of desiccants (SAR Section D.5). Without the presence of water, the staff agrees that corrosion of the internal package components or fuel will not occur.
615	States that the design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport.	See #637
637	The design of the package shall take into account temperatures ranging from -40°C to +70°C for the components of the packaging. Attention shall be given to freezing temperatures for liquids and to the potential degradation of packaging materials within the given temperature range.	The neoprene in the o-rings and valves has a usable range between -50°C and 150°C. Since the temperature range to use the package is between -20°C and 73°C, the neoprene will withstand the operating conditions neoprene can stand the usage (SAR Sections B.3, B.4.3). The mechanical properties of the SS400 carbon steel show no decrease at temperatures down to -40 ^{o}C (SAR Fig. 11-A.5. The staff agrees with these conclusions. This package contains no liquids that can freeze. The 637 requirements are met.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
638	The design and manufacturing techniques shall be in accordance with national or international standards, or other requirements, acceptable to the competent authority.	SAR Section III_A states that a QA management system based on ISO9001 shall be established The first document in this system is a QA manual "that defines standards of QA activities required at each stage of design, fabrication, handling, inspection, and maintenance. The materials of construction are specified to Japanese standards in the SAR. The RSI response gave equivalent US standards. .
642	The design of any component of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.	See #613
646(b)	A package shall be so designed that if it were subjected to the tests specified in paragraphs. 719-724 [Type A package tests], it would prevent loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the package.	Only the fuel assemblies and external cylinder of the package are considered shielding. (SAR Section II D.3.1 (1)). The mechanical and thermal properties of the fuel assembly, and confinement system components in various tables throughout the SAR were spot checked, by the staff, and found to be correct. The physical parameters (dimensions, internal pressures) were also spot checked and found to be correct.
648(b)	Either be provided with sufficient absorbent material to absorb twice the volume of the liquid contents. Such absorbent material must be suitably positioned so as to contact the liquid in the event of leakage; or be provided with a containment system composed of primary inner and secondary outer containment components designed to ensure retention of the liquid contents, within the secondary outer containment components, even if the primary inner components leak.	This package is transporting fresh fuel assemblies. They have never been in water and contain no liquids. The only available moisture would be from condensation from the air since the assemblies are shipped in dry air (SAR Section 1.D.5). Since no liquids are present this regulation is met.

3.0 THERMAL EVALUATION

The purpose of the thermal review is to verify that the package design satisfies the thermal safety requirements of the IAEA *Regulations for the Safe Transport of Radioactive Material*, TS-R-1. The staff reviewed the thermal material properties, the descriptions of the thermal modeling, the assumptions used in the thermal analyses, and the calculations provided by the thermal models for normal transport and accidental transport under the revalidation request for MFC-1 fissile material package with 14x14, 15x15, and 17x17 fuel rods configurations.

The purpose of the MFC-1 package is to transport fresh UO_2 fuel assemblies made up of enriched natural uranium PWR fuel assemblies. The MFC-1 is categorized as a Type A fissile material package to meet the IAEA requirements for NCT, both hot and cold, and Hypothetical Accident Conditions (HAC), as described in the thermal requirements of

IAEA TS-R-1. The design of the package is described in Section I of the SAR for the model MFC-1 package.

3.1. Packaging

The thermal test, as defined by the IAEA TS-R-1 regulations, follows the mechanical tests to account for the most damaging conditions for the MFC-1 package. Subsequent to the HAC mechanical tests, the fuel cladding had not been ruptured. This was confirmed by post HAC helium leak tests. The applicant determined that the package is modeled with no deformation in a horizontal position under the NCT while the package is modeled taking into account the deformation under transport of the HAC. For the thermal analyses, the applicant employed conservative assumptions regarding the behavior of the fuel rod cladding as a function of temperature.

The staff evaluated the following risks in the thermal review: 1) the temperature rise of the package due to solar insolation; and 2) the temperature rise of the package due to fire test after significant deformation generated from the drop tests. The applicant performed three dimensional analyses of the MFC-1 package with the thermal analysis code TRUMP to verify the thermal design of MFC-1 under NCT and HAC in compliance with the regulatory safety requirements of IAEA TS-R-1.

3.2. Modeling Setup for Confirmatory Analysis (NCT and HAC)

The staff reviewed the descriptions and the model calculations of MFC-1, checked the thermal properties used in the analyses, and evaluated the thermal performance under both NCT and HAC. The parameters and physical phenomena used in the applicant's evaluation of MFC-1 under NCT and HAC are summarized below:

NCT

1) The thermal properties of the materials are provided in SAR Thermal Calculation Package (II-B Thermal Analysis), including Zircaloy fuel rods, UO_2, wood, carbon, steel, and air. The physical properties of the materials (thermal conductivity, specific heat, viscosity, density) vary with temperature.
2) The ambient air is still with a temperature of 38°C.
3) The maximum temperature of the package is 73°C, and its minimum is -20°C.
4) The internal pressure rise of the packaging at the maximum temperature is 0.019 MPa.
5) Leak-tightness can be maintained under NCT.
6) The decay heat of the content can be negligible.
7) Heat transfer between the package surface and the surrounding environment by natural convection and radiation are taken into consideration.
8) No deformation of the packaging is observed under NCT.
9) No thermal stress can be produced since there is nothing to restrict the thermal expansion.

HAC (thermal/fire test)

The package was exposed to a fire of 800°C for a period of 30 minutes with a calorific value of 0 W.

1) The initial temperature of the thermal test is 73°C for the whole region of the package (based on the temperature calculation results for NCT).
2) The HAC mechanical tests do not breach the fuel rod cladding which forms the containment boundary. This is confirmed by the post HAC helium leak tests.
3) The emissivity of the surface of the package before, during, and after the HAC thermal test is modeled to be 1.0, 0.9, and 1.0 respectively.
4) Heat transfer between the package surface and the surrounding environment by both forced convection and radiation are taken into consideration.
5) The analysis was performed taking into consideration the deformation of the package produced due to the HAC mechanical tests.
6) The maximum temperature of the fuel rods is 490°C, which is lower than their allowable temperature limit of 570°C.

The fuel rods experienced a maximum pressure of 8.34 MPa G and a corresponding stress of 61.2 MPa which is below its stress criteria of 260 MPa.

3.3. Conclusions

The applicant predicted that the maximum temperature of the MFC-1 package under NCT and HAC are 73°C and 490°C, respectively. The staff reviewed the package model descriptions, input parameters and boundary conditions of the thermal analysis, thermal properties of the packaging material, and verified the temperature distributions under NCT and HAC.

The staff concludes that the thermal evaluation is conservative and acceptable for the MFC-1 package based on the conditions considered in the thermal analyses such as: 1) the package is subject to a hot ambient temperature of 38°C for NCT; 2) the initial temperature of the package is set as 73°C for HAC fire test; 3) the deformation of the package is considered to increase heat conduction into the package for HAC fire test; 4) the package is exposed to an 800°C fire for a period of 30 minutes with an emissivity of 0.9 for HAC fire test; and 5) the package is exposed to a hot ambient temperature of 38°C for post-fire cool down.

Therefore, the staff confirmed that the thermal design of MFC-1 package generally meets the requirements for thermal performance outlined in IAEA TS-R-1 for the transportation of the fuel assemblies. The staff has reasonable assurance that the MFC-1 package will perform as designed for shipments made in accordance with the applicable Certificate of Compliance.

The summary of the TS-R-1 requirements related to the thermal evaluation of the MFC-1, along with the staff's findings, is provided in Section 3.4.

3.4. IAEA Regulations Applicable to Thermal Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
501	REQUIREMENTS BEFORE THE FIRST SHIPMENT (501) Sets requirements that must be fulfilled before the first shipment of any package.	Requirement met.
501 (b)	For each Type B(U), Type B(M), and Type C package and for each package containing fissile material, it shall be ensured that the effectiveness of its shielding and containment and, where necessary, the heat transfer characteristics and the effectiveness of the confinement system, are within the limits applicable to or specified for the approved design.	Requirement met. MFC-1 transport type A fresh fuel.
502	REQUIREMENTS BEFORE EACH SHIPMENT (502) Sets requirements that must be fulfilled prior to each shipment of any package.	Requirement met.
502(a)	For any package it shall be ensured that all the requirements specified in the relevant provisions of these Regulations have been satisfied.	Requirement met.
502(c)	For each Type B(U), Type B(M), and Type C package and for each package containing fissile material, it shall be ensured that all the requirements specified in the approval certificates have been satisfied.	Requirement met.
502(d)	Each Type B(U), Type B(M), and Type C package shall be held until equilibrium conditions have been approached closely enough to demonstrate compliance with the requirements for temperature and pressure unless an exemption from these requirements has received unilateral approval.	Regulation is not applicable. MFC-1 is a type A package.
507	OTHER DANGEROUS PROPERTIES OF CONTENTS (507) Sets the requirements of other dangerous properties of the package contents, such as explosiveness, flammability, pyrophoricity, chemical toxicity, and corrosiveness that should be taken into account in the packing, labeling, marking, placarding, storage and transport in order to be in compliance with the transport regulations for dangerous goods of each of the countries through or into which the materials will be transported, and, where applicable, with the regulations of the cognizant transport organizations, as well as these Regulations.	Requirement met. MFC-1 is to deliver fresh fuel, in compliance with transport regulations.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
617	ADDITIONAL REQUIREMENTS FOR PACKAGES TRANSPORTED BY AIR (617-619) Sets requirements for packages transported by air. For packages to be transported by air, the temperature of the accessible surfaces shall not exceed 50°C at an ambient temperature of 38°C with no account taken for insulation.	Regulation is not applicable. The MFC-1 is not transported by air.
618	Packages to be transported by air shall be so designed that, if they were exposed to ambient temperatures ranging from -40°C to + 55°C, the integrity of containment would not be impaired.	Regulation is not applicable. The MFC-1 is not transported by air.
631	Packages designed to contain 0.1 kg or more of UF_6 shall not be provided with pressure relief devices.	Regulation is not applicable. The MFC-1 is not used to transport UF_6.
637	The design of the package shall take into account temperatures ranging from -40°C to +70°C for the components of the packaging. Attention shall be given to freezing temperatures for liquids and to the potential degradation of packaging materials within the given temperature range.	Regulation met. The initial ambient temperature is -20°C for cold test and 38°C for NCT.
642	The design of any component of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.	Regulation met. No gas is generated by radiolysis.
643	The containment system shall retain its radioactive contents under a reduction of ambient pressure to 60 kPa.	Regulation is not applicable. The MFC-1 is a Type A package.
644	All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve.	Regulation met.
651(a)	Alter the arrangement, the geometrical form or the physical state of the radioactive contents or, if the radioactive material is enclosed in a can or receptacle (for example, clad fuel elements), cause the can, receptacle or radioactive material to deform or melt; or	Regulation is not applicable.
651(b)	Lessen the efficiency of the packaging through differential thermal expansion or cracking or melting of the radiation shielding material; or	Regulation is not applicable.
651(c)	In combination with moisture, accelerate corrosion.	Regulation is not applicable.
652	A package shall be so designed that the temperature of the accessible surfaces of a package shall not exceed 50°C, unless the package is transported under exclusive use.	Regulation is not applicable.
653	The ambient temperature shall be assumed to be 38°C.	Regulation is not applicable.
654	The solar insulation conditions shall be assumed to be as specified in Table XI.	Regulation is not applicable.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
655	Requires that for a package which includes thermal protection in order to satisfy the 30 minute thermal test, the protection on the exterior of the package shall not be rendered ineffective by ripping, cutting, skidding, abrasion, or rough handling.	Regulation is not applicable.
676	A package for fissile material shall be designed for an ambient temp. range of -40 degrees C to +38 degrees.	Regulation met.
728(a)	Exposure of a specimen for a period 30 minutes to a thermal environment which provides a heat flux at least equivalent to that of a hydrocarbon fuel/air fire in sufficiently quiescent ambient conditions to give a minimum average flame emissivity coefficient of 0.9 and an average temperature of at least 800□°C, fully engulfing the specimen, with a surface absorptivity coefficient of 0.8 or that value which the package may be demonstrated to possess if exposed to the fire specified, followed by:	Regulation met.
728(b)	Exposure of the specimen to an ambient temperature of 38°C, subject to the solar insolation conditions specified in Table XI and subject to the design maximum rate of internal heat generation within the package by the radioactive contents for a sufficient period to ensure that temperatures in the specimen are everywhere decreasing and/or are approaching initial steady state conditions.	Regulation met.
736	Enhanced thermal test: The conditions for this test shall be as specified in para 728, except that the exposure to the thermal environment shall be for a period of 60 minutes.	Regulation is not applicable. A 60 minute thermal test is not required.
807 (a)	A detailed description of the proposed radioactive contents with reference to their physical and chemical states and the nature of the radiation emitted;	Requirement met (1-D Contents of Packaging)
807 (b)	A detailed statement of the design, including complete engineering drawings and schedules of materials and methods of manufacture;	N/A
807 (c)	A statement of the tests which have been done and their results, or evidence based on calculative methods or other evidence that the design is adequate to meet the applicable requirements;	N/A
807 (d)	The proposed operating and maintenance instructions for the use of the packaging;	N/A
807 (e)	If the package is designed to have a maximum normal operating pressure in excess of 100 kPa gauge, a specification of the materials of manufacture of the containment system, the samples to be taken, and the tests to be made;	N/A

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
807 (g)	Any special stowage provisions necessary to ensure the safe dissipation of heat from the package considering the various modes of transport to be used and type of conveyance or freight container;	N/A
810 (d)	The range of ambient conditions (temperature, solar radiation) which are expected to be encountered during transport and which have been taken into account in the design.	N/A
813	An application for approval shall include all information necessary to satisfy the competent authority that the design meets the requirements of para. 671 and a specification of the applicable quality assurance program as required in para. 310.	Requirement met.

4.0 CRITICALITY EVALUATION

4.1. Packaging

The applicant performed all criticality analyses using the SCALE 4.4 code package, which has been validated and recognized in the international community for the ENDF/B-V cross section library used in the applicant's calculations. SCALE 4.4 was re-validated by the applicant for PWR fuel systems with no credit for accumulated burnup. The benchmark problems used to perform this validation are representative of benchmark arrays of PWR fuels with the following characteristics:

- water moderation
- boron neutron absorbers
- close-fitting water reflection
- unirradiated light water reactor type fuel (no fission products or "burnup credit") near room temperature (vs. reactor operating temperature)

The applicant performed this validation to provide the basis for determining the Upper Subcritical Limit (USL) for the SCALE 4.4 CSAS25 control module with the 238-group ENDF/B-V cross section library for the fuel assemblies approved for the MFC-1 package. The USLs determined as a function of several parameters presented in these validation calculations are applicable to the MFC-1 package with 17x17 12 ft fuel assemblies and other smaller fuel assemblies that have these general characteristics. In addition, the essential parameters (e.g., Average Energy Group Causing Fission) of the system being analyzed fell within or close to the range of applicability for each parameter addressed in these calculations.

The USL for 17x17 12 ft fuel assemblies, including an administrative subcriticality margin of 0.05, was 0.9382. The maximum calculated k_{eff} by the applicant for an infinite array of 17x17 12 ft fuel assemblies with 100% water moderation in the void areas inside the package, but outside the fuel rods, and with full water reflection outside the package was 0.9340, which is below the USL.

The staff performed independent confirmatory evaluations of the MFC-1 Transportation Package with 17x17 12 ft fuel assemblies using the CSAS25 sequence of the SCALE 5.1 code package with the 238-group ENDF/B-V cross-sections. These calculations were performed to ensure the maximum calculated k_{eff} occurs at 100% water moderation in the void areas of the MFC-1 package. Using assumptions similar to the applicant's for arrays of packages under hypothetical accident conditions, the staff's confirmatory calculations resulted in a maximum k_{eff} similar to what was reported in the application. The maximum k_{eff} occurred at a 100% water density.

4.2. Criticality Findings

Based on the review of the competent authority's certificate, the statements and representations contained in the application (as supplemented), and staff confirmatory calculations, the staff agrees that the MFC-1 package meets the standards in IAEA Safety Standards Series No. TS-R-1, Rev. 2005, subject to the conditions in the letter. The summary of the TS-R-1 requirements related to the criticality evaluation of the MFC-1, along with the staff's findings, is provided in Section 4.3.

4.3. IAEA Regulations Applicable to Criticality Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
501	Sets requirements that must be fulfilled before the first shipment of any package.	The application (see Table IV-A.1 and Appendix III-B) describes acceptance tests that affect components relied upon for the criticality analysis, such as checks performed for the neutron absorbers. The staff finds these tests to be acceptable and adequate to ensure the criticality design of the fabricated package.
501 (b)	For each Type B(U), Type B(M) and Type C package and for each package containing fissile material, it shall be ensured that the effectiveness of its shielding and containment and, where necessary, the heat transfer characteristics and the effectiveness of the confinement system, are within the limits applicable to or specified for the approved design.	The proposed contents are unirradiated reactor fuel elements. Thus, the contents do not generate heat or pressure, and the radiation is very low (<0.006 mSv/h at 1 meter from the outer surface of the package). Therefore, this paragraph does not apply.
501 (c)	For packages containing fissile material, where, in order to comply with the requirements of para. 671, neutron poisons are specifically included as components of the package, checks shall be performed to confirm the presence and distribution of those neutron poisons.	The cradle assembly contains four borated stainless steel plates, which serve as neutron absorbers for the fuel assemblies. Table IV-A.1 and Appendix III-B describes the acceptance tests that are performed for the neutron absorbers.
502	Sets requirements that must be fulfilled prior to each shipment of any package.	The competent authority's certificate lists in Conditions 7(4) and 10 the actions to be performed prior to each shipment. The application describes these actions in greater detail in Table IV-A.1.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
502(a)	For any package it shall be ensured that all the requirements specified in the relevant provisions of these Regulations have been satisfied.	The competent authority's certificate lists in Conditions 7(4) and 10 the actions to be performed prior to each shipment. The application describes these actions in greater detail in Table IV-A.1.
502(c)	For each Type B(U), Type B(M), and Type C package and for each package containing fissile material, it shall be ensured that all the requirements specified in the approval certificates have been satisfied.	The competent authority's certificate lists in Conditions 7(4) and 10 the actions to be performed prior to each shipment. The application describes these actions in greater detail in Table IV-A.1.
502(g)	For packages containing fissile material, measurements of isotopic composition (if burnup credit is allowed) and tests of the closure of the package (if special features are used to avoid in-leakage of water) shall be performed.	The contents are fresh fuel, and no special features are relied upon in the criticality assessment (other than an appearance check of the confinement system to confirm integrity of the confinement system). Therefore, the paragraph is not applicable.
528	The CSI for packages containing fissile material shall be obtained by dividing the number 50 by the smaller of the two values of N derived in para 681 and 682. The value of the CSI may be zero, provided that an unlimited number of packages is subcritical.	Criticality evaluations in the applicant's safety analysis demonstrate that an infinite array of damaged packages under hypothetical accident conditions, are adequately subcritical. The limiting value of "N" is therefore ∞, resulting in a CSI of 50/∞ = 0.
530	The transport index of any package or overpack shall not exceed 10, nor shall the CSI of any package or overpack exceed 50 except for consignments under exclusive use.	The CSI of the package is 0 and the TI is 0.6, therefore, the staff finds the requirement of this paragraph is met for criticality for non-exclusive use.
601	Requirements for LSA-III material (601) LSA-III material shall be a solid of such a nature that if the entire contents of a package were subject to the test specified in para. 703 the activity in the water would not exceed 0.1 A2.	This paragraph is not applicable as the current package is a fissile (type A) package.
629	Sets requirements for packages containing uranium hexafluoride (UF_6). Uranium hexafluoride shall be packaged and transported in accordance with the provision ISO 7195 [10], and the requirements of paras. 630-631. The package shall also meet the requirements prescribed elsewhere in these Regulations which pertain to the radioactive and fissile properties of the material.	The current package is not a UF_6 package; therefore, this paragraph does not apply.
632(a)	The packages are designed to requirements other than those given in ISO 7195 [10] and paras. 630-631 but, notwithstanding, the requirements of paras. 630-631 are met as far as practicable;	The current package is not a UF_6 package; therefore, this paragraph does not apply.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
632(c)	For packages designed to contain 9000 kg or more of uranium hexafluoride, the packages do not meet the requirement of para. 630(c).	The current package is not a UF_6 package; therefore, this paragraph does not apply.
651(a)	Alter the arrangement, the geometrical form or the physical state of the radioactive contents or, if the radioactive material is enclosed in a can or receptacle (for example, clad fuel elements), cause the can, receptacle or radioactive material to deform or melt; or	The proposed contents are unirradiated reactor fuel elements. Thus, the contents do not generate heat. Therefore, this paragraph does not apply.
651(b)	Lessen the efficiency of the packaging through differential thermal expansion or cracking or melting of the radiation shielding material; or	The proposed contents are unirradiated reactor fuel elements. Thus, the contents do not generate heat. Therefore, this paragraph does not apply.
671(a)	Maintain subcriticality during normal and accident conditions of transport; in particular, the following contingencies shall be considered: water leaking into or out of packages; the loss of efficiency of built-in neutron absorbers or moderators; rearrangement of the contents either within the package or as a result of loss from the package; reduction of spaces within or between packages; packages becoming immersed in water or buried in snow; and temperature changes; and	The applicant's analysis includes consideration of water leakage into the package, including the effects of preferential flooding due to features that may restrict water flow into or from different void spaces within the package. Variation of moderator density was also considered as well as the effects of tolerances on the fuel contents and eccentric positioning of the contents. Based upon its review of the applicant's evaluation and independent confirmatory analyses, staff finds the evaluation to be acceptable and that it demonstrates that the package remains subcritical.
671(b)	Meet the requirements: of para. 634 for fissile material contained in packages; prescribed elsewhere in these Regulations which pertain to the radioactive properties of the material; and specified in paras. 673-682, unless excepted by para. 672.	Smallest external dimension of the package is larger than 10 cm; package meets regulations pertaining to the radioactive properties of the contents; paras. 673 – 682 discussed in the appropriate rows for each TS-R-1 paragraph below.
672	Fissile material meeting one of the provisions (a)–(d) of this para. is excepted from the requirement to be transported in packages that comply with paras. 673-682 as well as the other requirements of these Regulations that apply to fissile material. Only one type of exception is allowed per consignment.	The current package is a type A package; therefore, based upon the package designation and the package contents, this paragraph does not apply.
672(a)	A mass limit per consignment such that: Refer to equation and Table XII - Consignment Mass Limits for Exception from the Requirements for Packages Containing Fissile Material.	The current package is a type A package; therefore, based upon the package designation and the package contents, this paragraph does not apply.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
672(b)	Uranium enriched in uranium-235 to a maximum of 1% by mass, and with a total plutonium and uranium-233 content not exceeding 1% of the mass of uranium-235, provided that the fissile material is distributed essentially homogeneously through the material. In addition, if uranium-235 is present in metallic, oxide, or carbide forms, it shall form a lattice arrangement.	The current package is a type A package; therefore, based upon the package designation and the package contents, this paragraph does not apply
672(c)	Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by mass, with a total plutonium and uranium-233 content not exceeding 0.002% of the mass of uranium, and with a minimum nitrogen to uranium atomic ration (N/U) of 2.	The current package is a type A package; therefore, based upon the package designation and the package contents, this paragraph does not apply
672(d)	Packages containing, individually, a total plutonium mass not more than 1 kg, of which not more than 20% by mass may consist of plutonium-239, plutonium-241 or any combination of those radionuclides.	The current package is a type A package; therefore, based upon the package designation and the package contents, this paragraph does not apply
673	Contains requirements for fissile material for which the chemical or physical form, isotopic composition, mass or concentration, moderation ratio or density, or geographic configuration is not known.	N/A – fresh fuel chemical and physical form, isotopic composition, mass, concentration, and geometric configuration are well known.
674	For irradiated nuclear fuel the assessment of paras. 677-682 shall be based on an isotopic composition demonstrated to provide (a) the maximum neutron multiplication during the irradiation history, or (b) a conservative estimate of the neutron multiplication for the package assessments. After irradiation but prior to shipment, a measurement shall be performed to confirm the conservatism of the isotopic composition.	The MFC-1 fuel element contents are fresh (i.e., unirradiated) fuel; therefore, this paragraph does not apply.
677	For a package in isolation, it shall be assumed that water can leak into or out of all void spaces of the package, including those within the containment system. However, if the design incorporates, special features to prevent such leakage of water into or out of certain void spaces, even as a result of error, absence of leakage may be assumed in respect of those void spaces. Special features shall include the following:.	The package does not incorporate special features to prevent in-leakage of water (other than an appearance check of the confinement system to confirm integrity of the confinement system). The criticality analysis assumes flooding of all package voids; therefore, the requirements of this paragraph are met. It is assumed that the water exists both inside and outside the package and the accommodated fuel assemblies are completely flooded with the water, but no water leaks into the fuel rods because the integrity of the containment system (fuel rods) can be maintained.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
677(a)	Multiple high standard water barriers, each of which would remain watertight if the package were subject to the tests prescribed in para. 682(b), a high degree of quality control in the manufacture, maintenance and repair of packagings and tests to demonstrate the closure of each package before each shipment; of	This package does not include special features to prevent in-leakage of water (other than an appearance check of the confinement system to confirm integrity of the confinement system), and the criticality analysis assumes flooding of all package voids; therefore, this paragraph is not applicable It is assumed that the water exists both inside and outside the package and the accommodated fuel assemblies are completely flooded with the water, but no water leaks into the fuel rods because the integrity of the containment system (fuel rods) can be maintained.
678	It shall be assumed that the confinement system shall be closely reflected by at least 20 cm of water or such greater reflection as may additionally be provided by the surrounding material of the packaging. However, when it can be demonstrated that the confinement system remains within the packaging following the tests prescribed in para. 682(b), close reflection of the package by at least 20 cm of water may be assumed in para 679(c).	Individual package is modeled with at least 20 cm of water external to the package outer shell.
679	The package shall be subcritical under the conditions of paras. 677 and 678 with the package conditions that result in the maximum neutron multiplication consistent with: (a) routine conditions of transport (incident free); (b) the tests specified in para. 681(b); (c), the test specified in para. 682(b)	The applicant has demonstrated that the maximum reactivity associated with the package under routine conditions of transport or hypothetical accident conditions, is adequately subcritical, per the criticality analysis described in Section II-E.
680	For packages to be transported by air: (1) the package shall be subcritical under conditions consistent with the tests prescribed in para. 734 assuming reflection by at least 20 cm of water but no water inleakage; and (b) allowance shall not be made for special features of para. 677 unless, following the tests specified in para. 734 and, subsequently, para. 733, leakage of water into or out of the void spaces is prevented.	No criticality analyses were performed to demonstrate compliance with this paragraph, nor were the necessary tests performed for demonstrating acceptability for transport by air. Therefore, this package may not be transported by air. This restriction will be a condition of staff's recommendation for revalidation.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
681	A number “N” shall be derived, such that five times“N” shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication consistent with the following:	An array of packages under normal conditions of transport was not evaluated explicitly; the applicant considered that this array would be bounded by the applicant’s analysis of arrays of damaged packages under hypothetical accident conditions. The staff finds this to be acceptable based upon the clearances between the contents becoming smaller due to the deformation of the damaged packages under hypothetical accident conditions, resulting in more conservative calculations than those for normal conditions. Therefore, the requirements of this paragraph are met by a demonstration of the subcriticality of the arrays of damaged packages under hypothetical accident conditions. The applicant’s analysis of arrays of damaged packages under hypothetical accident conditions demonstrates that an infinite array of packages remain subcritical. Therefore, N = ∞.
681(a)	There shall not be anything between the packages, and the package arrangement shall be reflected on all sides by at least 20 cm of water, and	See comments for 681.
681(b)	The state of the packages shall be their assessed or demonstrated condition if they had been subjected to the test specified in paras. 719-724.	See comments for 681.
682	A number "N" shall be derived, such that two times "N" shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication consistent with the following:	The applicant has demonstrated that an infinite array of damaged packages under hypothetical accident conditions, are adequately subcritical. The limiting value of “N” is therefore ∞, resulting in a CSI of 50/∞= 0.
682(a)	Hydrogenous moderation between packages, and the package arrangement reflected on all sides by at least 20 cm of water; and	The applicant’s model considers moderation between packages and the array is reflected by 20 cm of water on all sides. It is assumed that water exists both inside and outside the package, and the accommodated fuel assemblies are completely flooded with water, but no water leaks into the fuel rods because the integrity of the containment system (fuel rods) is maintained.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
682(b)	The tests specified in paras. 719-724 followed by whichever of the following if the more limiting: the tests specified in para. 727(b) and, either para. 727(c) for packages having a mass not greater than 500 kg and an overall density not greater than 1000 kg/m³ based on the external dimensions, or para. 727(a) for all other packages; followed by the test specified in para. 728 and completed by the tests specified in paras. 731-733; or the test specified in para. 729; and	The applicant neglected everything outside the package inner shell. The hypothetical accident condition tests did not result in any deformation to the package inner shell, the basket, or the dummy fuel element used in the tests. Based upon there being no changes to the packaging and that silicone rubber spacers are placed above and below the fuel element to maintain its vertical location in the basket, the staff finds this model to be acceptable for the criticality analysis. The applicant considers flooding of all void spaces within the package. The applicant considered uniform partial density moderation in the package and preferential flooding with varying moderator densities. Staff reviewed the analysis and finds that the applicant adequately considered preferential flooding for the fuel contents.
682(c)	Where any part of the fissile material escapes from the containment system following the tests specified in para. 682(b), it shall be assumed that fissile material escapes from each package in the array and all of the fissile material shall be arranged in the configuration and moderation that results in the maximum neutron multiplication with close reflection by at least 20 cm of water.	No fissile material escaped after the tests specified in para. 682(b), therefore, this paragraph does not apply.
731	Packages for which water in-leakage or out-leakage to the extent which results in greatest reactivity has been assumed for purposes of assessment under paras. 677-682 shall be excepted from the test.	Water in-leakage is assumed in the criticality analysis for the package, therefore this test is not performed.
733	The specimen shall be immersed under a head of water of at least 0.9 m for a period of not less than eight hours and in the attitude for which maximum leakage is expected.	The applicant's criticality analysis assumes water in-leakage into the package. Therefore, the result of this test does not impact the criticality evaluation.
806(a)	A package design for fissile material, which is also subject to paras. 812-814, shall require multilateral approval; and	This package is a type A package; therefore, this paragraph does not apply.
807	Provides the requirements for the information which must be contained in an application for approval for Type B(U) and Type C packages.	This package is a type A package; therefore, this paragraph does not apply.
807 (a)	A detailed description of the proposed radioactive contents with reference to their physical and chemical states and the nature of the radiation emitted;	This package is a type A package; therefore, this paragraph does not apply.

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
807 (b)	A detailed statement of the design, including complete engineering drawings and schedules of materials and methods of manufacture;	This package is a type A package; therefore, this paragraph does not apply.
807 (c)	A statement of the tests which have been done and their results, or evidence based on calculative methods or other evidence that the design is adequate to meet the applicable requirements;	This package is a type A package; therefore, this paragraph does not apply.
807 (d)	The proposed operating and maintenance instructions for the use of the packaging;	This package is a type A package; therefore, this paragraph does not apply.
807 (f)	Where the proposed radioactive contents are irradiated fuel, the applicant shall state and justify any assumption in the safety analysis relating to the characteristics of the fuel and describe any pre-shipment measurement required by para. 674(b);	This paragraph does not apply because the proposed contents are fresh (i.e., unirradiated) fuel elements.
810 (b)	Any proposed supplementary operational controls to be applied during transport not regularly provided for in these Regulations, but which are necessary to ensure the safety of the package or to compensate for the deficiencies listed in (a) above;	This package is a type A package; therefore, this paragraph does not apply.
810 (c)	A statement relative to any restrictions on the mode of transport and to any special loading, carriage, unloading or handling procedures; and	This package is a type A package; therefore, this paragraph does not apply.
812	Each package design for fissile material which is not excepted according to para. 672 from the requirements that apply specifically to packages containing fissile material shall require multilateral approval.	This paragraph does not describe a requirement that is applied as part of the review of the criticality safety design of a package.
813	An application for approval shall include all information necessary to satisfy the competent authority that the design meets the requirements of para. 671, and a specification of the applicable quality assurance program as required in para. 310.	As described in the foregoing sections of this table, the staff finds that the application meets this requirement with respect to the criticality safety design of the package.

5.0 OPERATIONS AND MAINTENANCE EVALUATION

5.1. Operations

The SAR contains instructions for installing and securing fuel assemblies within the package, verifying the integrity of both neutron poisons and O-rings, tightening bolts to close the package, installing tamper indicating seals and verifying both radiation levels and contamination levels are within regulatory limits. The SAR also contains instructions for removing fuel assemblies from the package.

5.2. Maintenance

The SAR contains instructions for the performance of periodic inspections of the packaging and various components. These inspections occur at least annually. The inspections verify the structural integrity of both the outer shell and internal components, insure valves can perform their design function and that neutron absorbing materials are free from harmful cracks, deformation, etc.

5.3. Operations and Maintenance Findings

Based on the review of the competent authority's certificate, the statements and representations contained in the application (as supplemented), the staff agrees that the MFC-1 package meets the standards in IAEA Safety Standards Series No. TS-R-1, Rev. 2005, subject to the conditions in the letter. The TS-R-1 regulations relevant to this package with respect to package operations, acceptance tests, and maintenance program are listed in Section 5.4.

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5.4. IAEA Regulations Applicable to Operation and Maintenance Evaluation

TS-R-1 Regulation	Summary of TS-R-1 Regulation	Applicability to MFC-1 Package
807 (d)	The proposed operating and maintenance instructions for the use of the packaging;	Regulation met. Staff reviewed the operating and maintenance instructions and determined them to be adequate.
807 (g)	Any special stowage provisions necessary to ensure the safe dissipation of heat from the package considering the various modes of transport to be used and type of conveyance or freight container;	Regulation is not applicable. The proposed contents do not generate heat.

CONDITIONS

The NRC recommends revalidation of Japanese Competent Authority Certificate J/105/AF-96, Rev. 2, for use in the United States with the following conditions:

(1) packages must be fabricated in accordance with Figures III-A-1, -4, -6, and -7 in Appendix III, and Table 1-C.1 in Section 1 of the Safety Analysis Report;
(2) the package contents are limited to those specified in the Japanese Competent Authority Certificate; and
(3) transport by air is prohibited.

CONCLUSIONS

Based on the statements and representations contained in the application, as supplemented, the staff concludes the Model No. MFC-1 package design, with the above stated conditions meets the IAEA requirements of TS-R-1, Rev. 2005.

Issued with letter to R. Boyle, Department of Transportation, on April 7th, 2011.