UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT

Docket No. 71-3092
Model No. TNF-XI Package
French Certificate F/381/AF-96
Revision EI

Enclosure 1

Table of Contents

Page

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT
Docket No. 71-3092
Model No. TNF-XI Package
French Certificate F/381/AF-96
Revision EI

SUMMARY

By letter dated July 14, 2021 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML22061A162), the U.S. Department of Transportation (DOT) requested that the U.S. Nuclear Regulatory Commission (NRC) staff perform a review of the French Certificate of Approval No. F/381/AF-96, revision EI for the TNF-XI transportation package and make a recommendation concerning the revalidation of the package regarding the addition of content 9 as described in the French certificate.

The NRC reviewed the information provided to DOT by TN Americas LLC in its application for the Model No. TNF-XI package against the regulatory requirements of the International Atomic Energy Agency (IAEA) Specific Safety Requirements No. SSR-6 (SSR-6), “Regulations for the Safe Transport of Radioactive Material,” 2012 Edition. Based on the statements and representations in the information provided by DOT and the applicant, the staff recommends the revalidation of the French Certificate of Competent Authority (CoA) No. F/381/AF-96, revision EI, Model No. TNF-XI package, for shipment of the contents as described in Section 1.2, “Contents,” of this safety evaluation report (SER).

1.0 GENERAL INFORMATION

Document No. DOS-19-022728-001, Revision 2, of the safety analysis report (SAR) includes a description of the Model No. TNF-XI package. Section 1.1 of this SER also includes a brief description of the package. The design was previously reviewed by the NRC and revalidation of the French Certificate of Approval No. F/381/AF-96, Revision Dk, recommended on August 12, 2019 (ML19219A036).

1.1 Packaging Description

The TNF-XI package has a box-shaped stainless-steel packaging. The main components of the package are the packaging body, a primary lid, and the lower face of the package. No changes were made to the packaging in this amendment.

Per the application, the packaging is compliant with the drawing in Chapter 0, Appendix 1, of the SAR (DOS-06-00037028-005, revision 2).

1.2 Contents

The applicant requested to add Content No. 9 to the Competent Authority Certificate for the Model No. TNF-XI. Content No. 9 consists of uranium oxides (UO_2, UO_3 or U_3O_8) in the form of powder, pellets, or scraps of pellets.

The maximum permissible uranium oxide mass per cavity of the packaging is defined according to the maximum enrichment rate of the U-235, its physical form, and its density. There are two categories, Case A and Case B, as seen in *Section 1.2.1 Uranium Oxides, Additives and Impurities* of the application.

Case A includes both pellets and powder, whereas Case B only allows for the powder form. Mass limits contained in the application are included for both forms. Allowable impurity limits are listed in the application for the powder form in each case.

Limits on the mass of additives with a greater hydrogen content than water are included for each case in the application.

1.3 Drawings

The packaging is constructed and assembled in accordance with the following drawing from SAR document DOS-06-00037028-005, revision 2:

Drawing No. 12986-01, Revision K   TNF-XI Design Drawing

2.0 STRUCTURAL EVALUATION

The objective of the structural review is to verify that the TNF-XI transportation package has adequate structural strength to withstand mechanical loads during normal conditions of transport (NCT) and accident conditions of transport (ACT) and determine whether it meets the requirements of the IAEA SSR-6.

2.1 Description of Structural Design

The proposed TNF-XI transportation package is a containment vessel designed to transport five different types of fissile material content. The structural analysis of the packaging is based on a total packaging mass of 1,050 kg with a maximum content mass of 300 kg. The transportation package body has a rectangular parallelepiped shape with an overall nominal section of 1,100 mm x 1,100 mm and a height of 940 mm (without the forklift paths). The main body of the package is comprised of four major structural components:

(1) four inner wells (cylindrical cavities) with a maximum diameter of 354 mm for retaining the radioactive material (where each cylindrical cavity is surrounded by a wall made of two stainless steel shells,1 mm thick each, which are separated by a space filled with a neutron poisoning resin),
(2) four primary lids containing a bayonet style closure systems with elastomer gasket construction for the inner wells (the primary lids can be either machined or welded in),
(3) four thermo-mechanical protection upper plugs for the primary lids, and
(4) an outer shell/casing made of 2 mm thick stainless steel sheets.

Other features include the phenolic foams which fill the base and side of the packaging body and the space between the inner wells. All the accessible surfaces are made of stainless steel material. Forklift guides at the packaging bottom are also provided to facilitate lifting and handling of the package.

The applicant lists all the packaging components, including the associated materials and mechanical properties in Chapter 0 (DOS-19-022728-001, Version 2.0) of the SAR, Tables 0.1

and 0.2. The applicant also provided the general assembly drawings of the TNF-XI transportation package in documents 12986-04-B, -C and -D, and 12986-06-A, and -B of the application.

During the review, the staff noted in 4.4 of Chapter 0 (DOS-19-022728-001, Version 2.0) and SAR Sections 2.2 of Chapter 0 A (DOS-19-022728-002, Version 2.0) that the application describes a spacer system used to maintain a 10 mm clearance between the packaging and the content, and a reinforcement steel disk. However, it is not clear if these components are credited with a structural function and/or if they are intended to be part of the package design, which resulted in the issuance of an RAI. RAI 2-1 and the applicant response are documented in ADAMS Accession No. ML22118A341.

In its response, the applicant stated that the reinforcement steel disk has no structural function since it is only used to facilitate welding operations and the associated inspections during assembly. The applicant also stated that the spacers system does not provide an essential structural function since it is used to fix the initial position of the content into the cavity to reduce the differential velocity between the content and the package. The applicant further stated that the spacers system was not identified in the list of package components in Chapter 0 of the SAR because they are part of the content.

During the evaluation of the applicant's response to RAI 2-1, the staff noted that the applicant provided the information necessary to clarify the function of the reinforcement steel disk and the spacers system. The NRC staff finds the applicant's response acceptable because the reinforcement steel disk and the spacers system are not credited to perform a structural function for the transportation package, and they are considered part of the package's content.

The NRC staff reviewed the application for completeness and accuracy and finds that the applicant adequately incorporated information related to the geometry, dimensions, materials, components, and relevant details of the major structural components of the TNF-XI transportation package. Therefore, the NRC staff finds that the transportation package description meets the regulatory requirements of IAEA SSR-6.

2.2 Structural Analysis Methodology for the Transportation Package

The applicant seeks to demonstrate compliance with the performance standards required in the regulations by demonstrating the ability of the package to withstand the tests representative of NCT and ACT, as stipulated in IAEA SSR-6, and as it applies to Type A packages and to packages intended for the transport of fissile materials. Specifically, paragraph 648 in IAEA SSR-6 requires the design of the package be able to prevent, after the tests: (a) loss or dispersal of the radioactive contents, and (b) more than a 20% increase in the maximum radiation level at any external surface of the package.

Test results were also used to validate the results of numerical calculations performed using conventional materials stress and strain formulas. The tests were performed using full scale prototype (or specimen) packages. The applicant also analyzed the strength of the TNF-XI packaging tie-down and handling devices, including its stacking configuration, for routine transport, and handling conditions. The following sections include discussions of the information provided by the applicant related to the strength tests and analyses performed for the TNF-XI transportation package, and a summary of the NRC staff's evaluations.

2.3 Evaluation of Lifting and Tie-Down Devices

In SAR Sections 4.6 and 6 of Chapter 0, the applicant stated that the TNF-XI transportation package is designed to be loaded and unloaded to an International Organization for Standardization 20-feet (ISO 20) dry shipping container using a forklift. Therefore, the package is equipped with three forklift paths at the bottom of the package to allow access during handlings. The applicant also stated that the bottom of the package was further reinforced with 3 mm thick stainless steel corners that are welded to the outer envelope of the package to prevent potential perforations when using the forklift. The loaded transportation package is further immobilized just by stowing the packages into the ISO 20 container in a configuration such that 20 TNF-XI or dummy packages are placed together. As described in the application, restraints will only be necessary in the case that there are not enough packages to fill the ISO 20 dry shipping container.

2.3.1 Lifting Attachments

Paragraphs 608 and 609 of IAEA SSR-6 require that any lifting attachments on the package be designed such that it will not fail when used in the intended manner and if it fails, the package still meet the other requirements in the regulations. Since the package does not contain a lifting attachment that is considered a structural part of a package, the NRC staff finds that the package meets the regulatory requirements of IAEA SSR-6 for lifting attachments. The NRC staff evaluation of the applicant’s analysis of the included forklift paths for the resultant pressure due to a stacking configuration is provided in SER Section 2.4.2.

2.3.2 Tie-Down Devices

Paragraph 638 of IAEA SSR-6 requires that any tie-down attachments on the package be designed, so that the forces in those attachments shall not impair the ability of the package to meet the requirements in the regulations. As noted above, the package is designed such that 20 packages and/or dummies packages can be placed in a 20 ft-long shipping container on two levels, each comprising of five rows with two packages per row, and without the need of tie-downs devices. The package is further secured to the container using a wood spacer frame that is independent of the package and is located at each side and on the top of the package. These devices are designed and selected using the equations provided in SAR Section 3.1.2 of Chapter 1 (DOS-19-022728-014, Version 2.0) to ensure that a minimum contact surface is provided to prevent damage of the package’s external structure and foam, and to maintain the package’s structural integrity. The applicant developed equations by considering the package to be subject to acceleration forces during transport of 10 g, 5 g, and 2 g in the longitudinal, lateral, and vertical direction of travel, respectively. The applicant analyzed the maximum expected mass load of the package against the minimum crushing strength of the phenolic foam and concluded that sufficient contact pressure is available to withstand the imposed loads on the package in each direction. The applicant also stated that tie-down straps (e.g., lashing straps) may be used in the longitudinal and/or vertical direction around the package to secure it during transport when sufficient packages are not available to fill the container as intended. However, protective side and/or corner plates providing the minimum required contact surface, as specified in the SAR, shall be placed between the straps, and the package to protect the TNF-XI transportation package from the straps.

The NRC staff finds that none of these external devices are considered to be a structural part of a package and the package does not include a tie-down device that may also be considered a structural part of a package. The package structural integrity will be maintained by providing adequate surface protection, as determine to be necessary using the equations provided in the

SAR, for any external devices in contact with the package. The NRC staff reviewed the information, analysis and test results submitted by the applicant and finds that the design of the tie-down devices meets the regulatory requirements of IAEA SSR-6 for tie-down devices.

2.4 Evaluation under Normal and Accidental Conditions of Transport

Paragraph 719 of IAEA SSR-6 requires for the TNF-XI transportation package be subjected to a free drop test, a stacking test and a penetration test, preceded in each case by the water spray test to demonstrate the ability to withstand NCT. Additionally, the IAEA SSR-6 requires for the TNF-XI package be subjected to the cumulative effects of a mechanical test that consists of three different drop tests and a thermal test thereafter to demonstrate the ability to withstand ACT, as specified in paragraphs 727 and 728 of the regulation. Following these tests, the package needs to be subjected to a water immersion test.

In SAR Section 3.3 of Chapter 00-1 (DOS-19-022728-005, Version 2.0) and Section 4.1 of Chapter 1, the applicant describes the testing sequence established for each specimen based on the regulatory requirements and the combination of tests leading to the maximum overall damage to the package to meet the intent of the regulation. In SAR Figures 1 through 13 in Appendix 1-6 (12,986-Z-1-6, Revision 0), the applicant illustrates the different drop configurations used for testing the prototypes packages. For the stacking test, the applicant used numerical calculations, in lieu of testing, to demonstrate the package’s ability to maintain structural integrity during a stacking configuration. The applicant also performed drop simulations to account for the evolution of the characteristics of the materials due to temperature and the hardening aging effect of the phenolic foam. A summary of the NRC staff’s evaluations of these testing and analyses are provided below.

2.4.1 Water Spray Test

The applicant stated that the water spray testing was considered as not applicable and was not performed because it will have no effect on a stainless steel package design. Furthermore, the applicant stated that the package criticality study already considers unlimited quantities of water penetrating the cavity of the package. Therefore, the NRC staff finds that the water spray testing is not necessary since the effects of water penetrating inside the package was already considered within the package criticality study.

2.4.2 Stacking Evaluation

Paragraph 723 of IAEA SSR-6 requires subjecting the TNF-XI transportation package to a load equal to the greater of the following to determine the maximum compression stress on the package: (a) 5 times the maximum weight of the package, or (b) 13 kilopascals (kPa) times the vertical projected area of the package.

The applicant determined that option (a) is the most conservative load design for the package. In SAR Section 4.2.2 of Chapter 1, the applicant calculated the applicable stacking pressure loads, based on the guideline provided in IAEA SSR-6, for both the upper, and lower sections of the package to demonstrate that the package can maintain its structural integrity under stacking condition. The load was applied uniformly to the upper and the bottom part of the package, and the resulting pressures were compared with the applicable stress limits of the phenolic foam, the lateral plates of the external casing, and the forklift guides. The pressure load values were considerably lower than the buckling limits of the lateral plates, the forklift paths, and the crushing strength of the phenolic foam. Therefore, the applicant concluded that the TNF-XI meets the regulatory requirements of the stacking configuration.

The NRC staff reviewed the analysis and test results submitted by the applicant and finds that the applicant has demonstrated that the package meets the regulatory requirements of IAEA SSR-6 for stacking condition.

2.4.3 Drop Tests

Paragraphs 722 and 727 of IAEA SSR-6 require the TNF-XI transportation package be dropped onto a target so as to suffer maximum damage in the safety features of the package. For NCT, a free-fall drop distance of 1.2 m needs to be considered. For ACT, a free-fall drop distance of 9 m needs to be considered concurrently with the cumulative effects of the other tests specified in the regulations.

As summarized in SAR Tables 1.1 to 1.4 in Chapter 1, the applicant performed a series of sequential free-fall drop tests with various impact configurations to demonstrate compliance with the testing requirements in the regulations. These tests were performed using a series of five full scale prototypes (or specimens) and they were performed to account for both the normal and accident conditions of transport. Overall, these tests include: (1) penetration tests using a 6 kg bar drop from a 1 m distance, (2) free drop from a 1.2 m distance, (3) drop tests from a 1 m distance onto a punch bar, and (4) free drop from a 9 m distance. The drop test orientations were chosen so as to cause the maximum damage to the package. The applicant performed the drop tests in several configurations, called drop campaigns, to determine the most penalizing configuration for the package. After the drop campaign, the applicant was able to conclude that the containment system (the inner shells and the primary lids) was not breached during the series of drops. Furthermore, it was found that the minimum thickness of the neutron poisoning resin was maintained, as stated in SAR Appendix 5 of Chapter 1 (12986-Z-1-5, Revision 0).

In addition to the physical drop tests, in SAR Appendix 1-9 (DOS-19-022728-015, Version 1.0), the applicant further analyzed the TNF-XI transportation package to consider the temperature effect on the behavior of the package and the crushing effect of the impacted corner during a 10.2 m oblique drop. The applicant considered this to be the most penalizing drop configuration for the package and performed the analysis using a partial simplified model in LS-DYNA to simulate the package drop for the different temperatures. The results of the analysis were used to establish the minimal crushing on the foam that must be considered in the ACT thermal and criticality safety analyses. To validate the results of this numerical calculation, the applicant performed a supplementary free fall physical test from a 10.2 m distance using a sixth full scale prototype (i.e., specimen n°945). After the drop test, the applicant performed a complementary analysis of the compression tests on the phenolic foam (SAR Appendix 1.1 in Chapter 1) to demonstrate that the deformations considered in the safety analysis remain valid despite of the higher crushing stress observed during the supplementary drop test. Therefore, the applicant validated the simulated test results from the analysis and was able to demonstrate that the content within the package remained contained.

In SAR Appendix 8 of Chapter 1 (DOS-06-00037028-108, Revision 0), the applicant also analyzed the primary lid capacity to withstand the effects of an off-centered load. This analysis was performed using a partial simplified LS-DYNA model simulating a 9 m vertical drop onto the lid with imposed accelerations. This acceleration value conservatively bounds all expected values for the NCT and ACT drop scenarios, including the effects of aging phenolic foam hardening. Like the drop tests, the applicant was able to demonstrate that there is no rupture of the primary lid and that leak tightness is maintained after the impact event. These results were later confirmed by comparing the supplementary free fall test and the complementary analysis performed by the applicant.

The NRC staff reviewed the analyses and test results and finds that they meet the regulatory requirements of IAEA SSR-6.

2.4.4 Penetration Tests

Paragraphs 724 and 727 of IAEA SSR-6 require the TNF-XI transportation package be subjected to a penetration test targeting the center of the weakest part of the package, so that, if it penetrates sufficiently far, it will hit the containment system. For NCT, a bar having 3.2 cm in diameter with a hemispherical end and a mass of 6 kg must be selected and dropped from a 1 m distance. For ACT, the following tests are also specified: (a) a 15 cm in diameter solid mild steel bar dropped from a 1 m distance, and (b) a 500 kg mass from a solid steel plate 1 m × 1 m dropped horizontally from a 9 m distance (for packages having a mass not greater than 500 kg per IAEA SSR-6 paragraph 685(b)). Tests effects must be considered concurrently with the cumulative effects of the other test specified in the regulations.

As stated before, the applicant tested various configuration, and drop locations to ensure that the most severe drop conditions were considered. In SAR Tables 1 and 2 in Appendix 1-6 (12,986-Z-1-6, Revision 0), the applicant described the drop test sequences performed on various prototypes and their corresponding drop heights. The applicant performed the penetration test after the 1.2 m free drop test in order to combine the damages with that of the preceding accident drop tests. Furthermore, the 1 m penetration test was performed before and repeated after the subsequent free drop test from a height of 9 m to account for the fact that the phenolic foam does not have the same characteristics before and after the 9 m drop test. For the preliminary test specimens, the results showed neither puncture of the outer steel casing, nor cracking of the welds. For the qualification and complementary tests, the packaging suffered varied degrees of damage including local tearing of the outer steel casing and the upper plug where the puncture bar hit the package. In SAR Appendix 1-7 (DOS-06-00037028-107, Revision 0), the applicant re-executed the 1 m puncture test on the impacted upper plug. The results showed deformations of the impacted area, but no opening of the lid nor release of the content was observed. Therefore, the applicant concluded that the packaging did not show significant degradation of the leak tightness of the inner well cavity and that containment is maintained for an accident condition of transport.

The NRC staff reviewed the analyses and test results and finds that they meet the regulatory requirements of IAEA SSR-6.

2.4.5 Water Immersion Test

In SAR Section 4.3.4 of Chapter 1, the applicant stated that packaging is not leak tight under external overpressure and that criticality safety studies already consider unlimited quantities of water penetrating the cavity. Therefore, the packaging structure needs not to be subject to the loading of the water immersion test. The NRC staff finds that the water immersion test is not necessary since the effects of water penetrating inside the package was already considered within the package model criticality study and found to be acceptable.

2.5 Evaluation Findings

Based on the review of the statements and representations contained in the application, the NRC staff finds that the TNF-XI transportation package has an adequate design to withstand mechanical loads during NCT and ACT, therefore, the package meets the regulatory requirements of IAEA SSR-6. The staff recommends revalidation of the French Certificate of Approval No. F/381/AF-96 (Revision EI).

3.0 MATERIALS EVALUATION

The staff's materials review focused on the changes since the staff's most recent recommendation to revalidate the TNF-XI package (2019), including changes to the mechanical properties used in the structural analysis, containment seal specifications, and package inspection requirements.

3.1 Mechanical Properties

The applicant modified the mechanical properties for aluminum and two grades of stainless steel. The applicant updated the minimum values of tensile strengths and elongation that are used in the structural analysis. The staff reviewed these changes with respect to the applicable French Association Française de Normalisation (AFNOR) standards for stainless steel and aluminum and found that the minimum properties used by the applicant exceed the equivalent standards for both stainless steel grades and the aluminum. However, the applicant's procurement plan includes testing and validation steps to verify that these minimum mechanical properties are met. The applicant stated in SAR Chapter 0 that the essential parameters and conformity of the materials with minimum mechanical and thermal properties are provided in SAR Table 0.2 and in SAR Chapter 7A, Section 2.1, "Examination of purchasing and manufacturing documents." The applicant also stated that all documents and inspection, test and check reports for procurement and manufacturing should be in compliance with relevant specifications, procedures and quality assurance procedures as stated in Chapter 0. The staff finds these controls acceptable to ensure that the mechanical properties of the procured materials will be consistent with the values used in the structural analysis.

3.2 Seals

The applicant increased the maximum allowable temperature for the primary lid elastomer seal from the previous revalidation of the TNF-XI package. The applicant increased the maximum operating temperature in a fire accident. In a response to an NRC request for additional information regarding how the seal material is verified to be capable of operating at the new maximum operating temperature, the applicant provided criteria for qualification of the primary lid elastomer seal to ensure that any changes in seal properties due to thermal aging are limited. These criteria include limits on changes in hardness, reduction in tensile strength and decrease of elongation at break. Based on these requirements, the staff finds that the applicant has adequate controls in place to ensure that the primary lid elastomer seal will perform its sealing function during short-term elevated temperature exposures.

3.3 Damping and Thermal Insulation

3.3.1. Phenolic Foam

The applicant stated that phenolic foam is chlorine free where chlorine is less than 20 parts per million by weight. Additionally, the foam may contain some humidity by weight. This clarification is an editorial change and was previously stated in the applicant's response during the last revalidation. The staff concludes that this editorial change to provide additional clarification does not affect any safety functions of this package.

3.3.2. Fusible plugs

Applicant made a change in the number of fusible plugs used to release overpressure in foam in case of fire, which was an editorial correction. In addition, the applicant included the operating temperature range of the fusible plug glue, which adds clarity to the type of glue required for the fusible plugs. The staff concludes that this editorial change to provide additional clarification does not affect any safety functions of this package.

3.4. Content Reactions

The applicant added Content No. 9, consisting of uranium oxides in the form of powder, pellets or scraps, enriched to a maximum of 5 percent ^{235}U. The staff reviewed the new content and determined that it does not introduce any new chemical reactions, as the content is consistent with previously approved Contents No. 4, 7, and 8. This addition also has no additional impact on chemical reactivity. The applicant also modified Contents No. 2 and 4 by increasing the limitation on aluminum and carbon impurities. This increase in impurity levels is not expected to significantly affect content reactions. Therefore, the staff finds that the changes to the allowable package contents do not introduce chemical reactions that could impair the effectiveness of the package.

3.5. Impact Limiter Foam

The applicant added SAR appendix 1.1, which complements the package drop analysis that was previously reviewed by the staff in the 2019 revalidation. The staff notes that the new information did not change the results of the drop analysis, but rather provided greater insight into the impact limiter foam properties assumed in the analysis. Specifically, the applicant presented mechanical test data on the foam and evaluated the significance of measured foam properties versus those assumed in the drop analysis. The applicant concluded that the differences do not affect the validity of the conclusions of the original drop analysis, given the limited effects of the foam on the energy absorption capacity of the impact limiters. The staff reviewed the applicant’s evaluation and finds that the foam properties used in the package drop analysis remain acceptable, as any uncertainties in the foam properties are considered to be adequately bounded by the margins available in the results of the structural drop test.

3.6. Inspection and Testing

In SAR Chapter 6A, the applicant added visual inspections of the primary lid seal faces prior to each shipment to verify that they do not contain any defects that may affect their leak tightness. The applicant also provided greater certainty for when gasket seals on the primary lids will be replaced. Previously, the replacement was only when necessary. With the new revision, gaskets will be inspected every three years and replaced systematically. Finally, in Section 3 of Chapter 7A, the applicant added visual inspections of welds to be checked every three years to verify the absence of cracks. The staff finds the additional inspections and gasket replacement requirements to be acceptable because they provide added assurance of package performance.

3.7. Materials Conclusion

The staff reviewed the TNF-XI package materials and finds that the package design properly accounts for the mechanical performance, confinement capability, and chemical compatibility of package components under the loads and environments required for evaluation in IAEA SSR-6. The staff recommends revalidation of the French Certificate of Approval No. F/381/AF-96 (Revision EI).

4.0 THERMAL EVALUATION

The purpose of the thermal review is to revalidate that the TNF-XI package design satisfies the thermal safety requirements of the IAEA SSR-6. A summary of the staff's review is provided below.

4.1 Description of the Thermal Analysis

The applicant described in Document No. DOS-19-022728-016, Ver. 1, "Thermal Analysis in Normal and Accident Conditions of Transport," Section 2, that for normal conditions of transport, the maximum calculated temperature of the surface temperature of the package is 66 °C (151 °F). Because there is no decay heat for the contents, the surface temperature of the package is the maximum temperature for all contents and components during normal conditions of transport and it is compatible with all the packaging materials.

The applicant performed a three-dimensional (3D) thermal analysis using a 1/8 symmetry model in Document No. DOS-19-022728-018, Ver. 1, Appendix 2-5 to correlate the results with the P4 prototype fire test that is described in Reference No. 12986-Z-1-6, Ver. 0, Appendix 1-6, of the application. That thermal model is shown in Appendix 2-5, Figure 2-5. 4, "Meshing of the TNF-XI case A package." The applicant then used the thermal model that is shown in Appendix 2-5, Figure 2-5. 5, "Meshing of the TNF-XI case B package," to evaluate accident conditions. The applicant considered the regulatory insolation applied in consecutive cycles starting with 12 hours of sunlight, followed by 12 hours without sunlight, over a 24-hour day until steady-state conditions were reached. The applicant also considered initial conditions for the accident conditions thermal analysis that included the maximum seal temperature.

The applicant's accident conditions thermal fire analysis maximum temperature results for the primary lid seals is described in Appendix 2-5, Section 3.1.2. Based on staff's review of Appendix 2-5, Figure 2-5. 15, "Evolution of the maximal temperature – ACT – case B," the maximum seal temperature is at that maximum for approximately less than three minutes during the accident conditions thermal fire analysis, which is less than the seal temperature criteria that is allowed for five hours as described in the Document No. DOS-19-022728-001, Ver. 2, Section 7.4. The applicant's accident conditions thermal fire analysis also described that the content and internal fittings temperatures remain below their allowable limit for accident conditions, as shown in Appendix 2-5, Section 3.1.2.

The applicant also described in Document No. DOS-19-022728-016, Ver. 1 that, in a localized area, the temperature of the neutron poison resin exceeded the resin's temperature limit, which resulted in a local degradation of the neutron poison resin equal to a 2 mm thick layer that was conservatively modeled to be 9 mm. The staff confirmed that the applicant further described in Document No. DOS-19-022728-017, Ver. 1, "Chemical Composition of Damaged Phenolic Foam and Neutronic Resin," the use of a conservative reduction in the amount of resin thickness (removal of a 9-mm thick layer) within the criticality analysis in Chapter 5A of the application, in comparison to the thermal calculations and the fire tests performed on the resin and the package, where charred resin remains present.

The applicant also demonstrated in, "Thermal Analysis in Normal and Accident Conditions of Transport," Section 4, that the seal fill rate, or the increase in seal volume when the temperature increases from ambient to the seal's maximum temperature during accident conditions, is less than the free volume of the seal groove; therefore, the staff finds it to be acceptable that there is no risk of seal extrusion.

4.2 Evaluation Findings

Based on review of the statements and representations in the TNF-XI package application, the staff concludes that the applicant adequately described and evaluated the thermal design for the TNF-XI package and that the package meets the thermal requirements of the IAEA SSR-6. The staff recommends revalidation of the French Certificate of Approval No. F/381/AF-96 (Revision EI).

5.0 CONTAINMENT EVALUATION

The objective of this containment evaluation review is to verify that the Model No. TNF-XI package design satisfies the containment requirements of IAEA SSR-6 under NCT and ACT.

The applicant previously provided their containment analysis for the TNF-XI package in Section 2, “Confinement System” of Chapter 5A, “Criticality-Safety Analysis of TNF-XI Package,” (Document DOS-06-00037028-500, Rev. 6), of the SAR of the TNF-XI, Rev. 9.

5.1 Description of the Containment Boundary

The description of the containment boundary provided by the applicant in the SAR (Rev. 9) has not changed with the current application for revalidation.

5.2 Package Content Changes

The applicant requested the addition of Content No. 9 (which is described as non-irradiated uranium oxides and fully discussed in Section 3.2 of document DOS-19-022728-004 Ver. 1.0) which does not affect the previous approval. In the same document, the applicant also discusses the added option of placing any radioactive contents to be loaded into the package into bags as part of the loading process. This change does not impact the containment function of the package and also does not affect the previous approval.

5.3 Additional Package Testing

Finally, the applicant, in document DOS-19-022728-015, Ver. 1, “Test Report of an Oblique Drop on a Corner from a Height of 10.2m of a TNF-XI Specimen when Hot”, reports on the results of a drop test evaluations of the package in which they state (on Page 17): “This test shows that the assembly (bag, pails and lid) makes it possible to guarantee that the contents present in the bags are not dispersed outside of the packaging.” This result does not impact the overall conclusion of the applicant’s containment analysis, nor its conclusions about the containment performance of the TN-XI package. This added information also does not affect the previous approval.

5.4 Evaluation Findings

As there were no changes to the containment system for the TNF-XI package requested by the applicant, the package continues to meet the containment requirements of the IAEA SSR-6. Therefore, the staff recommends revalidation of French Approval Certificate of a Package Design, Number F/381/AF-96 (Revision EI).

6.0 SHIELDING EVALUATION

The staff reviewed the application to ensure that the Model No. TNF-XI provides adequate shielding from the proposed Content No. 9 and other SAR changes and verified that the package met the radiation level requirements within the IAEA SSR-6 for protecting people and the environment.

6.1 Shielding Evaluation under Normal Conditions of Transport and Accident Conditions of Transport

The staff evaluated the TNF-XI package with the addition of Content No. 9 in accordance with the requirements of IAEA SSR-6. Specifically, paragraph 526 of the SSR-6 requires that the transport index (TI) shall not exceed 10. Per paragraph 523 of the SSR-6, this means that the radiation level cannot exceed 0.1 mSv/hr (10 mrem/hr) at 1 meter from the package. Paragraph 527 of the SSR-6, for non-exclusive use packages, requires that the maximum radiation level at the surface of the package does not exceed 2 mSv/hr (200 mrem/hr). For Type A packages, paragraph 648(b) requires that the package be designed such that if it were subjected to the tests specified in paragraphs 719–724 (normal condition tests), it would prevent more than a 20% increase in the maximum radiation level at any external surface of the package.

The applicant presented its source term and shielding analysis of all of the allowable contents in Document No. DOS-19-022728-011, Version 1.0, “Dose Rate Calculations Around the TNF-XI Packaging Model,” including the proposed Content No. 9. This document included some additional modifications to the analysis since the prior revalidation. The staff reviewed the expected dose rate tables in this document for unirradiated uranium contents and it shows that the package meets regulatory requirements with significant margin. This is expected, as the contents allowed for the TNF-XI in certificate F/381/AF-96 are all in the form of unirradiated uranium, which does not have a significant radioactive source term. Further, since this is a Type AF package, contents are restricted to radioactive material limits in Table 2 of the SSR-6.

The staff found the addition of Content No. 9, as authorized content for the TNF-XI package, as well as other SAR changes will meet the requirements of paragraphs 523, 527, and 648(b) of the IAEA SSR-6 regulations.

6.2 Evaluation Findings

Based on review of the statements and representations in the TNF-XI package application and as discussed in the paragraphs above, the staff has reasonable assurance that the TNF-XI package meets the requirements in paragraphs 523, 527, and 648(b) in the IAEA SSR-6. Therefore, the staff recommends revalidation of French Approval Certificate of a Package Design, Number F/381/AF-96 (Revision EI).

7.0 CRITICALITY EVALUATION

The packaging in the revalidation is unchanged from that which had been previously approved by staff in prior SERs. The staff reviewed the application for revalidation of the TNF-XI package to ensure that the package will continue to remain subcritical under the requirements of IAEA SSR-6. The staff specifically focused the review on the addition of Content No. 9 as an allowable fuel type in the package against the respective applicable paragraphs of SSR-6.

7.1 Description of Criticality Design

The applicant requested to add Content No. 9 as an allowable fuel type in the TNF-XI package. Staff noted that the package is identical to a previously approved package that has been used for domestic transportation of fissile material (Certificate of Compliance (CoC) for the Model No. TNF-XI package, Docket Number 71-9301). The criticality design of the TNF-XI package remains unchanged from the previous package design approved by the NRC. The applicant continues to use neutron poison plates and borated resin neutron poison that have been approved for up to 75% credit of the entrained boron. Additional criticality control is based on limiting the mass of fissile material in the package based on enrichment.

7.2 Spent Nuclear Fuel Contents

The applicant requested the addition of Content No. 9 to the Competent Authority Certificate for the Model No. TNF-XI package. Content No. 9 may consist of various forms of unirradiated uranium enriched up to 5 weight percent (wt%) of Uranium-235 (^{235}U). These forms include low-density uranium oxides in the form of UO_2 powder or scraps and may be mixed with material that is more hydrogenated that water (i.e., CH_2) up to a SAR-specified limit of CH_2 per shipping cavity. There may be impurities in the fissile material, primarily carbon, aluminum, and zinc, with a limit specified on the total sum of impurities. Boron is present in the neutronic resin shell at a density described in chapter 5A of the application.

7.3 General Consideration for Criticality Safety

The applicant evaluated both a single package (SSR-6, para 680) and infinite array configurations (SSR-6, para 685) for both NCT and ACT by modeling an infinite array of TNF-XI packages, which bounded the single package analysis, by using total reflection of a single package. Staff agrees with this approach since the neutrons are conserved within the modeled cavity and neglects any neutron absorption or escape from the surrounding package materials and encompasses any potential mechanical or thermal damage to the package, yielding a conservative analysis.

The applicant also made many conservative assumptions in their criticality models, including filling void spaces in the cavities and pail with water at optimal moderation, ignoring the external shells of the upper plugs, increasing the density of the phenolic foam surrounding the cavities, and making conservative assumptions regarding the boron concentration of neutron resin shell. Each cavity can hold three pails, for which the applicant's criticality model conservatively neglected the stainless steel and space between each pail, yielding a cylinder of fissile bearing material that equated to three pails in height. The UO_2 powders and scrap are assumed to moderated by water and CH_2 in each cavity and are assumed to coalesce into a spherical geometry. The applicant also investigated the effects of heterogeneous moderation on the fissile material by assuming an array of spherical oxide fragments with various radii surrounded by the most reactive moderators (i.e., water or CH_2). The models used by the applicant as described in Figures 5A-7.1 through 5A-7.8 of the application show the package, potential damage, thermal damage to the neutron resin shell, and the axial and radial configuration of fissile material within the package.

7.3.1 Evaluation of Single package and Infinite Arrays of packages

The bounding parameter analysis of the applicant assumed a single package with up to 46 kgs of 5.0 wt% enriched ^{235}U UO_2 powder at optimum moderation in a spherical shape with the material centered in the bottom of the package cavity. The applicant also evaluated up to 66 kgs of 4.55 wt% and 75 kgs of 4.15 wt% enriched powders using the same general assumptions. The applicant modeled the TNF-XI package with the cavity filled with the bounding fissile contents, with mirrored reflection outside of the model. The maximum calculated multiplication factor was less than 0.95 for all three bounding cases. Since the conditions of the models are the same for the package array evaluation due to the full reflection of the model, the applicant's analysis bounds both the single package and an infinite array of packages since full reflection is a very conservative assumption. The staff finds this assessment to be acceptable, since the package body, lid, and base are stainless steel, the k_{eff} of the of the single package with the containment system reflected is bounded by the infinite array of packages.

7.3.2 Criticality Safety Index (CSI)

The applicant determined that the CSI for the TNF-XI package containing Content No. 9 remained at zero with the new proposed contents because the applicant demonstrated that an infinite array of packages under normal and accident conditions of transport remain subcritical. The staff finds that the applicant correctly calculated the CSI as defined in SSR-6, para 686, and therefore, it is acceptable.

7.4 Demonstration of Maximum Reactivity

The applicant performed a parametric study of the most reactive contents of the TNF-XI by evaluating 5.0 wt% UO_2 powder and evaluated the effects of the axial location of the fissile material in the cavities, varied the radial and axial location of the powder, moderation effects of CH_2, and the effect of the stainless steel plate at the top of the cavity. The applicant also modeled uranium oxide spheres in the cavity and found the optimal moderation of the system by varying the amount of water and CH_2 within each cavity. The most reactive configuration found for the 5.0 wt% case was then applied to the 4.55 wt% and 4.15 wt% cases. Several sensitivity studies were performed to obtain the most reactive configuration of the fissile material within the TNF-XI package, including the geometrical shape of the fissile contents, the position of the material within the cavity, various reflector materials to bound the possible residues, moderation within the cavity, and variable water density around the outside of the model.

Based on these criticality evaluations, the applicant found that the most reactive conditions for 5.0 wt% enriched UO_2 at a density and CH_2 content specified in the SAR and unlimited water were with a spherical fragment radius of 0.30 cm with fissile material moderated by water in the bottom of the cavity and the internal containers located at the top of the cavities, the CH_2 located at the center of the cavity and radially centered in the internal container, the remainder of the cavities filled with water, and the reinforcement tube and burnt phenolic foam replaced by air. These same varying parameters were then applied to the 4.55 wt% and 4.15 wt% UO_2 powders, both at the same maximum density in a similar fashion to determine the maximum reactivity of each enrichment limit. In all cases, the maximum calculated multiplication factor was less than 0.95.

The staff evaluated the proposed TNF-XI package with Content No. 9 as an allowable content and compared it to the previously approved TNF-XI package analysis (CoC for Docket No. 71-9301). The applicant performed calculations using the CRISTAL V1.2 system of codes using the MORET4 Monte Carlo calculation code and the APOLLO2 macroscopic cross-section code new Content No. 9 using similar modeling techniques to the 71-9301 analysis to evaluate NCT and ACT using optimum moderation, water intrusion, and package tolerances. In all instances, the applicant's calculated k_{eff}'s were below the acceptance criteria of $k_{eff} + 3\sigma = 0.950$. The staff performed confirmatory calculations based on the information provided by the applicant in Chapter 5A-7 using the SCALE 6.1 computer code system with the

KENO VI three-dimensional Monte Carlo code and the continuous energy ENDF/B-VII cross-section library using assumptions similar to those used by the applicant. The staff's calculations confirmed the applicant's results for the addition of Content No. 9 in the TNF-XI package. The staff finds that the maximum reactivity meets the acceptance criteria of $k_{eff} + 3\sigma = 0.95$.

7.5 Evaluation Findings

The staff found that the proposed addition of Content No. 9 in the TNF-XI package will remain subcritical for all routine, normal, and accident conditions of transport. The staff based its finding on its verification of adequate system modeling performed by the applicant. The acceptance standard of a maximum k_{eff} of 0.95 was maintained for all analyzed scenarios and meets the requirement that the package maintain subcriticality under all conditions of routine, normal and accident conditions as required by the IAEA SSR-6, paragraphs 637(a) and 682. Therefore, the staff recommends revalidation of French Approval Certificate of a Package Design, Number F/381/AF-96 (Revision EI).

8.0 CONDITIONS

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

a. The package design must be in agreement with Chapter 0, "Description of the TNF-XI Packaging Model," Document No. DOS-19-022728-001, Revision 2;
b. The package must be prepared for shipment and operated in accordance with Chapter 6A, "Typical Operating Instructions of the Packaging," Document No. DOS-19-022728-012, Revision 2; and Chapter 7A, "Acceptance Test and Maintenance Program," Document No. DOS-19-022728-003, Revision 1;
c. The package must be maintained and operated in accordance with Chapter 8A, "Quality Assurance Applicable to TNF-XI Package Model," Document No. DOS-19-022728-013, Revision 1, of the application; and
d. The package must be fabricated in accordance with Design Drawing No. 12986-001, Revision K.

9.0 CONCLUSION

Based on the statements and representations presented in the Safety Analysis Report and supplemental information, the staff agrees that the package meets the standards in IAEA Safety Standards SSR-6, 2012 Edition. The staff recommends that DOT revalidate French Certificate of Approval No. F/381/AF-96, Revision EI, for import and export use, with the conditions listed above.

Issued with letter to R. Boyle, U. S. Department of Transportation.

Revalidation of French Certificate of Approval F 381 AF-96, Revision EI for the TNF-XI Package DATE June 10, 2022

DISTRIBUTION:
KJamerson, NMSS/MSST/MSEB
ADimitriadis, R-I/DNMS/DIRHB
BDesai, R-II/DRS/EB3
MKunowski, R-III/DNMS/MIB
GWarnick, R-IV/DNMS/RIB

ADAMS Accession No.: ML22153A088; ML22153A090

OFFICE	NMSS/DFM/STLB	NRR/DEX/ESEB	NMSS/DFM/CTCFB	NMSS/DFM/NARAB
NAME	NDevaser *ND*	JLopez *JL*	CBajwa *CB*	JSmith *JS*
DATE	Jun 2, 2022	Jun 2, 2022	Jun 2, 2022	Jun 6, 2022
OFFICE	NMSS/DFM/CTCFB	NMSS/DFM/STLB	NMSS/DFM/MSB	NMSS/DFM/FFLB
NAME	JIreland *JI*	SFigueroa *SF*	OKhan *OK*	MDiaz *MD*
DATE	Jun 3, 2022	Jun 2, 2022	Jun 2, 2022	Jun 6, 2022
OFFICE	NMSS/DFM/MSB	NMSS/DFM	NMSS/DFM/STLB	NMSS/DFM/STLB
NAME	TBoyce JWise for *JW*	DMarcano *DM*	YDiaz-Sanabria CJacobs for *CJ*	NDevaser *ND*
DATE	Jun 7, 2022	Jun 9, 2022	Jun 10, 2022	Jun 10, 2022

OFFICIAL RECORD COPY