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

May 13, 2020

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

SUBJECT: REVALIDATION RECOMMENDATION FOR THE GERMAN CERTIFICATE OF APPROVAL NO. D/4377/AF-96, REVISION 0, MODEL NO. ANF-10 PACKAGE (DOCKET NO. 71-3095)

Dear Mr. Boyle:

By letter dated May 30, 2019 (Agencywide Documents Access and Management System Accession No. ML19176A254), the U.S. Department of Transportation (DOT) requested our assistance in the revalidation review of the Model No. ANF-10 package for import and export use, as authorized by the German Certificate of Approval No. D/4377/AF-96, Revision 0.

Based upon our review, the statements and representations contained in the application, and for the reasons stated in the enclosed safety evaluation report, we recommend revalidation of the German Certificate of Approval No. D/4377/AF-96, Revision 0, for the Model No. ANF-10 package.

If you have any questions regarding this matter, please contact me or Nishka Devaser of my staff at (301) 415-5196.

Sincerely,

John B. McKirgan Digitally signed by John B. McKirgan
Date: 2020.05.13 11:08:18 -04'00'

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

Docket No. 71-3095
EPID L-2019-LLA-0116

Enclosures:
1. Safety Evaluation Report
2. German Certificate of Approval No. D/4377/AF-96, (Revision 0) in English (ADAMS Accession No. ML19176A254)

SUBJECT: REVALIDATION RECOMMENDATION FOR THE GERMAN CERTIFICATE OF APPROVAL NO. D/4377/AF-96, REVISION 0, MODEL NO. ANF-10 PACKAGE (DOCKET NO. 71-3095)

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NUCLEAR REGULATORY COMMISSION
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# SAFETY EVALUATION REPORT

**Docket No. 71-3095**
**Model No. ANF-10 Package**
**Certificate of Approval No. D/4377/AF-96**
**Revision 0**

Enclosure 1

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**Certificate of Approval No. D/4377/AF-96**
**Revision 0**

## SUMMARY

By letter dated May 30, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19176A254 [DOT, 2019]), U.S. Department of Transportation (DOT) requested our assistance in the revalidation review of the Model No. ANF-10 transportation package for import and export use as authorized by the German Certificate of Competent Authority D/4377/AF-96, Revision 0.

The NRC reviewed the information provided to the DOT by TN Americas LLC in its application for the Model No. ANF-10 package and its supplements 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 (IAEA, 2012). Based on the statements and representations in the information provided by DOT and the applicant, the staff recommends the revalidation of the German Certificate of Competent Authority D/4377/AF-96, Revision 0, Model No. ANF-10 package, for shipment of the contents including non-irradiated fuel assemblies or rods as described in Section 1.1.2, "Contents," of this safety evaluation report (SER).

## 1.0 GENERAL INFORMATION

The ANF-10 shipping container is composed of the following components:

- container bottom section,
- container lid,
- top end cover with two guide tubes and head adapter,
- two inner protective channels with foot adapters (foot adapters removed as modification for transport of fuel rods),
- polyethylene and composite foam plates enclose the inner protective channels, and
- shipping tubes in the inner protective channels (modification for transport of fuel rods), and
- an outer protective cladding which consists of three connected sections (the U-shaped bottom section of the container, the top end cover, and the container lid).

The inner protective channels consist of the U-shaped bottom section of the protective channel with a metal cover sheet on the bottom and the protective channel cover. The channels are made of austenitic steel sheets. The outer protective cladding is made of laminated aluminum honeycomb with aluminum cover sheets, which are encased on all sides with austenitic steel sheet.

## 1.1 Package Description

### *1.1.1 Packaging*

The ANF-10 is a package for the transport of non-irradiated (fresh) fuel assemblies and rods. A container may contain up to a maximum of two boiling water reactor (BWR) assemblies with or without the fuel assembly channel and are transported as bundles in a shipping tube.

The fuel assemblies in the package are protected at the top by a square guide tube made of austenitic steel sheet at least 3 mm thick. The shipping tube for the transport of fuel rods consists of an austenitic steel tube and is closed at the head-side end with a screwed-on close-off cap. The container walls, which are part of the outer protective cladding, are enclosed all round with smooth, austenitic steel sheet.

The package is composed of the following components: container bottom, container cover, head cover with two guide tubes and top-end adapters, two inner protective boxes with bottom-end adapters and the enclosure of the inner protective boxes with polyethylene and foam material. The top-end and bottom-end adapters are removed for transporting fuel rods in shipping tubes. The container walls, the central divider in the container bottom, the container cover and the head cover, which form part of the outer protective enclosure are made of multiple layers of aluminum honeycombs covered with aluminum sheeting and are enclosed on all sides by austenitic steel plates.

### *1.1.2 Contents*

The certificate of approval states that there are two permissible types of contents:

A) <u>Non-irradiated Fuel Assemblies</u>: A maximum of two BWR assemblies with non-irradiated enriched uranium which consist of four fuel rod partial bundles. The four partial bundles are mounted in a fuel assembly channel and contain uranium oxide pellets and gadolinium oxide/uranium oxide pellets with a maximum U-235 enrichment of 5%. The pellets are enclosed in zirconium alloy cladding tubes. The fuel assemblies must contain 16 gadolinium oxide fuel rods with a (minimum) of 0.5% $Gd_20_3$ content in relation to the mass and a pellet density of 10.943 g/cm$^3$.

B) <u>Non-irradiated Fuel Rods</u>: These are BWR rods, packed in maximum two fuel rod shipping tubes. The fuel rods contain uranium oxide pellets or gadolinium oxide/uranium oxide pellets and they are enclosed in zirconium alloy cladding tubes, whose outside diameter is at least 9.80 mm. The number of fuel rods is limited by the shipping tubes capacity and admissible (composition-dependent) overall mass only.

## 2.0 STRUCTURAL EVALUATION

The purpose of the structural evaluation is to verify that the structural performance of the package meets the regulatory requirements of IAEA SSR-6 (IAEA, 2012).

## 2.1 Description of Structural Design

The ANF-10 transportation package is a containment vessel to transport Type A quantities of radioactive material in solid form. It is designed to protect the package contents during transport for both normal and hypothetical accident conditions, as required by IAEA SSR-6 (IAEA, 2012).

The package (confinement system) is comprised of the following principal components:

- container bottom, container cover, and head cover with two guide tubes and top-end adapters

- two inner protective boxes with bottom-end adapters and the enclosure of the inner protective boxes with polyethylene and foam material

- outer protective enclosure comprised of the container walls, the central divider in the container bottom, the container cover, and the head cover

The package is approximately 4,725 mm (186 inches) in length, 668 mm (27 inches) in width, and 362 mm (14.25 inches) in height and the containment function is performed by the fuel rod cladding tubes.

The applicant provided the general assembly drawing (ANF, 2000b) (drawing number ANF-5-121-3075-03, Rev. 1) of the transportation package where it identified the major components of the package. The NRC staff reviewed the drawing and finds that the applicant adequately incorporated information related to the geometry, dimensions, material, components, notes, and relevant details of the major components of the ANF-10 package.

## 2.2 Codes and Standards

The ANF-10 package is manufactured using specifications as approved by the competent authorities as required.

## 2.3 General Requirements for Type A packages

### *2.3.1 Minimum Package Size*

The smallest external dimension is significantly larger than the requirement of 10 cm.

### *2.3.2 Positive Closure*

Positive closure is achieved by the fabrication process for the individual fuel rods.

### *2.3.3 Package Valves or other Devices*

This package contains no valves.

### *2.3.4 Continuous Venting*

Not applicable.

## 2.4 Lifting Standards

Calculations were performed to demonstrate that the package can be lifted safely. The results indicated an acceptable margin of safety when compared with allowable stresses. Procedures were also developed to ensure that no part of the package will fail when used for its intended purpose and further, that if failure of those components should occur, the package could still continue to meet other safety requirements.

## 2.5 Structural Evaluation under Normal Conditions of Transport

The following sections include a discussion of the information provided by the applicant, in the SAR, related to the structural analysis under normal conditions of transport for the ANF-10.

### *2.5.1 Heat*

The package was evaluated at 100°C and was found acceptable. Since the operating conditions are limited to an ambient temperature of approximately 38°C, the resulting evaluations can be considered conservative.

### *2.5.2 Cold*

The applicant's acceptance criteria for this package was that no loss of fissile material would occur in the event of a drop. Since the applicant performed the hypothetical accident condition evaluation at -40°C with no adverse effects on the package contents, that evaluation is considered bounding. Further, the applicant argued that even if the impact limiting materials were to fail completely, the acceptance criteria for no loss of fissile material would still be met.

### *2.5.3 Pressure*

The containment system (fuel rods) was evaluated for a reduced external pressure and found to be acceptable using a combination of physical testing and leak testing.

### *2.5.4 Vibration*

The applicant demonstrated that the package is resistant to vibration induce loads by illustrating that bolted closures had adequate procedures to ensure the required bolt torques. In addition, acceleration measurements under realistic road conditions demonstrated no significant impact to the performance of the package due to vibration induced loading.

### *2.5.5 Water Spray*

Not Applicable.

### *2.5.6 Free drop*

A free drop test of 1.3 m (4.3 feet) was performed and consisted of a slap-down configuration as determined by the applicant. The reported damage to the outer portion of the package was minimal, and it was concluded that the fuel rod containment integrity remained intact.

### *2.5.7 Stacking*

The applicant performed the stacking test utilizing 8,000 kg (17,637 lbs) of steel plate which exceeded the calculated requirement of 7,750 kg (17,085 lbs). The package experienced no damage from this test, as reported in the application.

### *2.5.8 Penetration*

The applicant reported no significant damage to the package due to a 3.2 cm (1.25 inch) diameter bar (weighing 6 kg [13.2 lbs]) striking the package after falling from a height of 1.2 m (3.93 ft).

### 2.6 Structural Evaluation under Hypothetical Accident Conditions

The applicant performed required drop tests to demonstrate compliance with the free drop test requirements in the IAEA SSR-6 (IAEA, 2012).

#### *2.6.1 Drop Test (9 meter, Test I)*

The applicant performed this test following a determination of the worst case drop orientation for the package. The test results demonstrated that there was no leakage from the individual fuel rods at -40°C, thus there is no safety concern. The applicant also asserted that the container and dummy elements were inspected and measured during post-test documentation. These measurements then formulated the basis for the criticality safety analyses.

#### *2.6.2 Puncture (1-meter, Test II)*

The SAR does not present specific results/findings for this test. Test results for the ANF-10 package for this test are presented in the German Federal Institute for Materials Research and Testing (BAM) "Test Report No. 20555 Instrumented Drop Tests Performed on the Prototype of an ANF-10 Shipping Container," (BAM, 1998). As indicated in the test report, no damage was observed on the fuel assemblies in the location of the puncture bar (mandrel).

#### *2.6.3 Crush (Test III)*

Not applicable since the package mass exceeds 500 kg.

#### *2.6.4 Thermal Test*

The applicant subjected the package to a thermal test by utilizing a furnace and heating the cladding tube temperature to 800°C. The applicant asserted that a leakage rate test was performed following the thermal tests and reported that no leakage of the fuel rods was detected, thus there was no safety concern.

#### *2.6.5 Immersion*

Applicant asserted that this test was not applicable to structural evaluation as there is an expectation of water in leakage during accident conditions.

### 2.7 Evaluation Findings

Based on the review of the statements and representations contained in the application, the NRC staff agrees that the ANF-10 transportation package meets the requirements of IAEA SSR-6 (IAEA, 2012).

## 3.0 THERMAL EVALUATION

The purpose of the thermal review is to verify that the package design satisfies the requirements for the thermal evaluation under IAEA SSR-6, (IAEA, 2012). The staff reviewed the thermal properties of the materials used to fabricate the Model No. ANF-10 package and the description of the thermal analysis, provided in the application and documents listed in Section 9 “References” of this SER, against the standards in SSR-6 (IAEA, 2012). A summary of the staff’s review is provided below.

### 3.1 Description of the Thermal Design

The Model No. ANF-10 is a Type A(F) package designed to transport unirradiated BWR fuel assemblies and fuel rods. The staff reviewed documents related to the thermal evaluation of the ANF-10.

Based on the staff's review of the application, the staff found that the applicant adequately described the thermal features of the ANF-10 package.

### 3.2 Thermal Evaluation under Normal Conditions of Transport and Hypothetical Accident Conditions

Staff confirmed that the design of the package has been evaluated for temperatures ranging from -40°C to +70°C.

As discussed in the containment section of this SER, the containment system of the ANF-10 system is formed by the gas-tight welded cladding tubes of the fuel rods. The outer packaging provides confinement for this Type A(F) package as the fuel cladding is the containment boundary and is designed to prevent the release of uranium from the fuel pellets. As such, the applicant performed a thermal test to determine fuel rod behavior under the IAEA specified hypothetical accident condition fire.

The applicant performed a thermal furnace test, as described in Siemens (2000b) and Siemens (2000c), using representative dummy rods shortened in comparison to the fuel rods specified as contents for the package, under the following conditions:

<u>A 30-minute fire test at 800°C.</u>

While the ANF-10 package itself was not tested, as this is a Type A(F) package where the fuel rods serve as the containment boundary and the applicant performed a thermal test using representative dummy rods, which remained leaktight following the test.

Based on the information reviewed, the staff concluded that the thermal tests performed demonstrate that the containment and sub-criticality functions of the ANF-10 package will not be negatively impacted during normal and accident conditions of transportation, as discussed in the applicable sections of this SER. Additionally, the staff finds the testing conducted acceptable to demonstrate that the package has been designed to meet the requirements under SSR-6 Paragraph 728, Thermal Test.

### 3.3 Evaluation Findings

Based on the review of the statements and representations in the application for the ANF-10 package, the staff concludes that the applicant adequately described and evaluated the thermal design of the ANF-10 package. Therefore, the package meets the thermal requirements of SSR-6 (IAEA, 2012).

## 4.0 CONTAINMENT EVALUATION

The purpose of the containment review is to verify that the package design satisfies the requirements for the containment evaluation under IAEA SSR-6, (IAEA, 2012). The staff reviewed the ability of the ANF-10 package to prevent the release of radioactive material in excess of those amounts specified in the regulations, as described in the documentation

provided in the application and documents listed in Section 9 “References” of this SER, against the standards in SSR-6 (IAEA, 2012). A summary of the staff’s review is provided below.

The containment system of the ANF-10 system is formed by the gas-tight welded cladding tubes of the fuel rods which are the proposed contents for this package. Welding of the cladding tubes is described in Section 7.3.2 of this SER.

As described in Sections 2.5 and 2.6 above, the fuel cladding maintains its structural integrity under normal and hypothetical accident conditions of transport.

Following the thermal test described in Section 3.2 above, the applicant noted an increase in the outer diameter of the dummy rods used during the test of a maximum of 1.5 mm and performed a helium gas leakage test on the dummy rods, which demonstrated leaktightness.

Based on the review of the statements and representations in the application for the ANF-10 package, and the existing certificate issued by a foreign competent authority (German Certificate of Approval No. D/4377/AF-96, Revision 0), the staff concludes that the applicant has adequately described and evaluated the design of the containment system for the ANF-10 package. Therefore, the package meets the containment requirements of SSR-6 (IAEA, 2012).

## 5.0 SHIELDING

Staff evaluated the ANF-10 package in accordance with the requirements of IAEA SSR-6 (IAEA, 2012) and limited the scope of its review to determine if the package will meet the requirements of SSR-6, paragraph 648(b). Staff also evaluated the dose rate requirements of SSR-6 paragraphs 528 and 573 which stipulate the following for consignments under exclusive use: the dose rate on any package surface does not exceed 1000 mrem/hr (10 mSv/hr); radiation levels at any point on the surface of the conveyance shall not exceed 200 mrem/hr (2 mSv/hr) and radiation levels at any point 2 m from the conveyance shall not exceed 10 mrem/hr (0.1 mSv/hr).

The applicant presented the contents parameters in Section 3.1 of the application. For two BWR assemblies, the package contains a maximum of 472 kg of uranium. For fuel rod shipping tubes, the applicant defined the radioisotopes in Table 4 of Certificate of Approval D/4377/AF-96 (Rev. 0). The applicant used the sum-of-fractions method per SSR-6 paragraph 430 to determine the maximum quantity of uranium allowed from the $A_2$ values of the isotopes listed in Table 1. In this case, the fuel rod shipping tubes may contain a maximum of 45.27 kg of uranium. The material for both cases must meet the definition of unirradiated uranium from ADR 2.2.7.1.3. This method is standard for unirradiated fuel and staff finds its use here acceptable. The applicant did not calculate maximum potential dose rates, but rather used measured samples. Staff finds this acceptable since the material is of low specific activity and unshielded dose rates are predicted to be within regulatory limits < 30 mrem/hr (0.3 mSv/hr) (“Classification of Uranium Fuel Assemblies as Substances of Low Specific Activity (LSA-III)”, ANF-2172-E, Revision 5, March 19, 2019).

The applicant separately evaluated drop scenarios to determine packaging deformation (ANF, 2000a). The applicant selected the scenario that resulted in the largest deformation, which is 1.83 cm. From its drop tests, the applicant determined a maximum reduction in distance of 2.3 cm from the surface of the package would still meet the requirement of SSR-6 paragraph 648(b) (ANF, 2000b), thus the calculated value is within the allowable range determined by the applicant. This is conservative as it minimizes the distance between the source and package surface.

Staff reviewed the applicant's reports and finds them acceptable since the applicant used conservative assumptions where applicable and the results show significant margin to the regulatory limits. Based on the statements and representations in the ANF-10 package application and as discussed in the paragraphs above, the staff has reasonable assurance that the ANF-10 package meets the requirements in paragraphs 528, 573, and 648(b) in IAEA SSR-6 (IAEA, 2012).

## 6.0 CRITICALITY EVALUATION

The staff reviewed the criticality safety aspects of the application to verify that the package design satisfies the requirements for the criticality evaluation under IAEA SSR-6, *Regulations for the Safe Transport of Radioactive Material*, 2012 Edition (SSR-6) (IAEA, 2012a). Staff reviewed the proposed contents of non-irradiated SVEA-96/L and SVEA-96 Optima2 BWR fuel types for this Type A package.

### 6.1 Description of Criticality Design

The ANF-10 transportation package consists of a container bottom, container cover, head cover with two guide tubes and top-end adapters, two inner protective boxes with bottom-end adapters, and an enclosure constructed of polyethylene and foam material forming the inner protective boxes. The ANF-10 outer protective enclosure is comprised of the container walls, the central divider in the container bottom, and the cover and head cover, and consist of multiple layers of aluminum honeycombs covered with aluminum plates encapsulated in austenitic steel plates. The inner box containing the fuel rods is composed of boron infused austenitic steel with a boron mass content of at least 0.8% and a thickness of at least 3mm.

### 6.2 Nuclear Fuel Contents

Only non-irradiated fresh fuel is allowed in the ANF-10 transportation package under this revalidation. Contents are limited to a maximum of two BWR fuel assemblies of type SVEA-96/L or SVEA-96 Optima 2, which consist of four fuel rod partial bundles that are mounted in a fuel assembly channel with an integrated water channel. Each fuel rod contains $UO_2$ pellets and $Gd_2O_3/UO_2$ pellets with a maximum enrichment of 5.0 wt.%. Pellets are encased in zirconium alloy cladding tubes. Up to 16 $UO_2$-$Gd_2O_3$ fuel rods with a minimum of 0.5% Gd2O3 content are allowed in each fuel assembly with a pellet density of 10.943 g/cm$^3$ and are arranged as shown in Appendix 2 of the SAR. Specific fuel conditions are specified in Tables 1 and 2 in Appendix 1 of the SAR. The fuel assembly channel has an internal maximum width of 125.8 mm, and the maximum gadolinia free end zones of the fuel rods are a maximum of 178 mm. Any partial length SVEA-96 Optima 2 fuel rods are defined in Appendix 2 of the SAR and accounts for missing partial length rods.

The other allowable contents in the ANF-10 transportation package are non-irradiated loose fuel rods packed in up to two fuel rod shipping tubes. Fuel rods may be composed of either $UO_2$ or $Gd_2O_3$-$UO_2$ pellets with zirconium alloy cladding. These fuel rods are defined in Table 3 of Appendix 1 of the SAR. The number of fuel rods allowed in the ANF-10 transportation package are limited by mass to 390 kg and a maximum enrichment of 5.0 wt.%.

Other allowable non-fissile contents include plastic and polyethylene inside the inner protective boxes. For the SVEA-96/L and SVEA-96 Optima 2 fuel assembly types, all plastics are limited to a maximum density of 1.04 g/cm$^3$ with a maximum hydrogen mass fraction of 11.8% and a maximum carbon mass fraction of 73.0%. For the loose rods in shipping tubes, all plastics are limited to a maximum density of 1.26 g/cm$^3$ with a maximum hydrogen mass fraction of 7.3%

and a maximum carbon mass fraction of 62.6%. Polyethylene is limited to a maximum density of 0.95 g/cm$^3$. Polyethylene for both configurations is limited to a maximum density of 0.95 g/cm$^3$.

### 6.3 General Considerations for Criticality Safety

The applicant evaluated a single package, arrays of packages under normal conditions of transport, and arrays under hypothetical accident conditions for the ANF-10 fresh fuel package for the assembly types SVEA-96/L and SVEA-96 Optima 2, as well as for loose rod configurations.

The applicant's analysis used computer modeling using the SCALE 6.1 code package with the 44-group ENDF/B-V cross section library and constructed models that were consistent with the as-designed package, including tolerances and material specifications of package components that maximize reactivity. The applicant considered deviations from nominal design configurations as well as package flooding effects.

### 6.4 Demonstration of Maximum Reactivity

Under IAEA SSR-6, a transportation package needs to remain subcritical under routing transport conditions, normal transport conditions, and accident transport conditions. The applicant analyzed various configurations of the ANF-10 transportation package loaded with BWR fuel assemblies SVEA-96/L or SVEA-96 Optima 2, using full water interstitial moderation and 300mm water reflection on all sides (ANF, 2018b). The applicant varied the fuel pin spacing to account for any shifting due to accident conditions, pellet diameter, and the inner diameter and wall thickness of the cladding. In all instances, the multiplication factor increased with increasing fuel rod pitch, and the highest $k_{eff}$ occurred when cladding thickness was minimized and with reduced fuel rod outer diameter. The applicant also analyzed the effects of higher moderating plastic and polyethylene under accident conditions, with the highest $k_{eff}$ occurring with polyethylene. Staff finds that the applicant's use of conservative assumptions and appropriate modeling techniques are appropriate for this transportation package and contents.

Under normal conditions of transport, the applicant calculated a CSI of 2.8, allowing up to 90 ANF-10 packages to be transported per conveyance, which was confirmed by staff. The maximum calculated $k_{eff}$ for the SVEA-96/L fuel assemblies was determined to be 0.89079 ± 0.00066, and 0.59411 ± 0.00035 for the SVEA-96 Optima 2 assemblies, respectively. Under accident conditions, the applicant evaluated the maximum multiplication factor assuming a 6x6 array moderated by polyethylene and found the $k_{eff}$ to be 0.83264 ± 0.0067. Staff reviewed the applicant's analysis and drawings and developed independent models for both the normal and hypothetical accident conditions that confirm the applicant's methodology and analysis. Based on the applicant's use of conservative assumptions, appropriate modeling techniques, and independent confirmation of results, staff finds that these results are acceptable for shipping SVEA-96/L and SVEA-96 Optima 2 fuel assemblies.

For the shipment of SVEA-96 Optima 2 fuel rods contained in transport tubes, the applicant performed a similar analysis as described in their SAR (ANF, 2018c). Under normal conditions of transport, the maximum $k_{eff}$ of the ANF-10 was calculated to be 0.70016 ± 0.00075 under flooded conditions, and 0.41123 ± 0.0003 under dry conditions. Under hypothetical accident conditions, the array of packages under flooding conditions yielded a maximum $k_{eff}$ of 0.91572 ± 0.00085 assuming a zero polyethylene, and 0.91566 ± 0.00071 assuming full moderation by polyethylene. Based on the applicant's use of conservative assumptions,

appropriate modeling techniques, and independent confirmation of results, staff finds that these results are acceptable for shipment of fuel rods in transport tubes.

### 6.5 Evaluation Findings

The staff found that the proposed contents of a maximum of two BWR fuel assemblies of type SVEA-96/L or SVEA-96 Optima 2, or SVEA-96 Optima 2 fuel rods contained in fuel tubes with a maximum enrichment of 5.0 wt% $^{235}$U will remain subcritical for all routine, normal, and accident conditions of transport for the contents specified in the Certificate of Approval D/4377/AF-96 (Rev. 0). The staff based its finding on its verification of adequate system modeling performed by the applicant and its own independent confirmatory analysis. The applicant maintained a maximum $k_{eff}$ acceptance standard for all analyzed scenarios and met the requirement that the package maintain subcriticality under all conditions of routine, normal and accident conditions as required by SSR-6 2012 edition Paragraphs 637(a) and 682.

## 7.0 MATERIALS EVALUATION

The purpose of the materials evaluation is to verify that the performance of the materials used to fabricate the package meets the regulatory requirements of IAEA SSR-6, 2012 Edition (IAEA, 2012).

### 7.1 Package Description:

#### 7.1.1 *Container*:

As described in the SAR Section 2 (ANF, 2018a) "Description of the Design," the applicant stated that all container components are constructed of laminated aluminum honeycomb (DIN standard 29978/DIN LN 29975, Type 5052) with aluminum cover sheets (SAE AMS-A-81596, Types 5052, 5251 or 5754) encased on all sides with austenitic steel sheet (cladding) fabricated to DIN EN 10088-2/DIN 17440, various Types.

In addition, the top end cover is fastened using (DIN EN ISO 3506-1), austenitic stainless steel, Group A3/A4/A5 (screws) onto the bottom section of the container and the container lid. Further, an austenitic steel square guide tube (DIN 17457, Types-similar to container) is bolted onto the top end cover by an adapter plate, which protects the fuel assembly.

#### *7.1.2 Inner Protective Channel:*

As described in the SAR Section 2.1.3, "Inner Protective Channels," the applicant stated one BWR fuel assembly, with or without fuel assembly channel, can be inserted. In addition, the inner protective channels are austenitic steel sheets fabricated to DIN EN 10088-2, which contain boron with a minimum content of 0.8 wt.-% boron in its natural composition. (Refer to Section 7.8 of this SER for acceptance testing). Further, the fuel assemblies have different lengths, as a result the remaining open spaces are equalized or fixed axially by head (i.e., top of container) and foot (i.e., bottom of container) adapters made of polyamide 12.

#### *7.1.3 Fuel Assemblies:*

As described in the SAR Section 3.3.1, "Fuel Assemblies," the applicant stated that the ANF-10 transports a maximum of two non-irradiated fuel assemblies of type SVEA-96/L or SVEA-96 Optima2 with enriched uranium consisting of four fuel rod partial bundles, 24 fuel rods each. In addition, the rods contain uranium oxide pellets and gadolinium oxide/uranium oxide pellets with

a U-235 enrichment of 5% maximum. Further, the pellets are enclosed in zirconium alloy (zircaloy-2) cladding rods. The applicant stated that the fuel rods form the fuel assembly together with the fuel assembly structure (i.e., spacers, water cross, top and bottom end pieces).

*7.1.4 Shipping Tubes:*

As described in the SAR Section 2.1.4, "Shipping Tubes," the applicant stated that the shipping tubes (two maximum) for the transport of non-irradiated fuel rods consists of an austenitic steel tube fabricated to DIN 17457 and the number of rods is limited by the tube capacity. The applicant stated that no foot adapters are utilized in the inner protective channel when the shipping container is used for transporting fuel rods within the shipping tubes.

## 7.2 Drawings:

The staff reviewed the drawings, SAR and associated document ANFG-11.103 (ANF, 2019b) and verified that the applicant provided an adequate description of the component safety functions, materials of construction, dimensions and tolerances, and fabrication (welding) specifications. The staff noted that the austenitic stainless steels used in the cladding of the ANF-10 shipping container are specified in the manufacturing document stated above as conforming to the "German Institute of Standardization," DIN EN 10088-2/DIN 17440 and there are several potential stainless steel types that could be used within that standard; however, the specific austenitic stainless steel plates and aluminum sheets mechanical property requirements are specified in Table 1 of document ANF (2000a), "Determination of the impact position and impact angles for the drop tests performed with shipping container ANF-10." Therefore, the staff finds that the applicant provided sufficient information in the drawings to describe the packaging materials.

## 7.3 Design Criteria:

*7.3.1 Codes and Standards:*

As described in the SAR the austenitic stainless steel used in the cladding of the ANF-10 container assembly conform to the DIN materials standard stated in this SER Section 7.2. In addition, the aluminum cover sheets and the laminated aluminum honeycomb conform to SAE material standard AMS-A-81596 and DIN standard 29978/LN 29975, respectively. The applicant stated that the manufacturer must have a certified quality assurance system (e.g., conforming to DIN EN ISO 9001 or ASME Code Section III NCA-3800). The staff finds the package's materials codes and standards to be acceptable because the applicant adequately provides material chemistry, mechanical properties, and fabrication requirements and their use conforms to the construction standards, as applicable.

*7.3.2 Weld Design and Inspection:*

As described in the SAR and document ANFG-11.103 (ANF, 2019b) welding is performed per the DIN welding standard 18800 Part 7, "Steel structures; manufacture, proofs of suitability," for using welders that are qualified per DIN EN 287, "Qualification test of welders - Fusion welding - Part 1: Steels."

The staff noted that the package drawings show that all confinement welds are inspected visually and with ultrasonic by a qualified inspector. In addition, the fuel rod cladding containment boundary welds and associated non-destructive testing are performed and

supplied by a fuel fabrication facility.  The staff reviewed the weld design and finds it to be acceptable because the applicant adequately describes welding and inspection and that the ANF-10 container will be performed in accordance to the German construction code.

## 7.4 Material Properties:

### *7.4.1 Mechanical/Thermal Properties:*

The staff noted that the applicant provided mechanical/physical parameters for steel (stainless) plate, aluminum sheet, aluminum honeycomb and foam in Tables 1 and 2 of report ANF, (2000a), "Determination of the impact position and impact angles for the drop tests performed with shipping container ANF-10."  The staff noted the parameters provided were used in the finite element (FE) model used for impact simulations.

Steels:

As described in the SAR and document ANFG-11.103 (ANF, 2019b) the applicant stated that the mechanical properties of the Types 304L, 321, 247 and 316 stainless steels acceptable for use in fabrication of the cladding for the ANF-10 container, were obtained from DIN EN 10088-2, "Stainless Steel - Part 2:  Technical Delivery Conditions for Sheets/Plates and Strips for General Purposes," and DIN EN 10088-3, "Stainless steels - Part 3:  Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes," and DIN 17457, "Cold formed welded steel structural hollow sections - Part 2:  Tolerances, dimensions and sectional properties."  The staff reviewed the temperature-dependent mechanical properties used in the applicant's mechanical calculations and confirmed that the properties are consistent with those the technical literature (e.g., ASME Code Section II).

Non-ferrous:

As described in the SAR and document ANFG-11.103 (ANF, 2019b) the applicant stated that the mechanical properties of the wrought aluminum alloy Type 5052 fabrication of the honeycomb cores for the ANF-10 container, were obtained from DIN LN 29975, "Aerospace - Honeycomb cores, hexagonal expanded, in wrought aluminum alloy 5052, corrosion protected, unperforated or perforated - Dimensions, masses," and of the wrought aluminum alloy Types 5052, 5251 and 5754 fabrication of the honeycomb cores were obtained from SAE AMS-A-81596, "Aluminum Foil for Sandwich Construction."  The staff verified the mechanical properties of aluminum alloys 5251 and 5754 from independent review of various technical literature (e.g., data sheets, handbooks, etc.) and confirmed that the properties are within the range of the parameters used for FE simulations.  The staff reviewed the temperature-dependent mechanical properties of alloy 5052 used in the applicant's mechanical calculations and confirmed that the properties are consistent with those the technical literature (e.g., ASME Code Section II).

Impact Limiter Foam:

As described in the SAR, document ANFG-11.103 (ANF, 2019b) and report ANF (2000a), "Determination of the impact position and impact angles for the drop tests performed with shipping container ANF-10," the applicant stated that the U-shaped bottom section of the protective channel and the spaces between neutron absorbing polyethylene plates and the walls of the bottom section of the container and the container lid are filled with polyethylene foam (ISPE 30 AXS) plates, which serve to absorb impacts.  The staff noted that the material conforms to the standards DIN 7726, DIN EN ISO 845, DIN 53 517, DIN EN ISO 1856, and

DIN EN ISO 3386-1. The staff noted that the SAR also refers to the polyethylene foam as a composite foam (Ethafoam) material, as PU foam, and that the material sheet specifies semi-rigid cellular material, closed-cell, polyethylene (PE). The applicant stated that polyethylene foam has a temperature resistance of -80°C to +90°C, however organic materials (foam materials) had undergone total combustion as a result of the hypothetical accident conditions fire. The applicant stated that the Ethafoam was assumed to be damaged with different damage depth for the ANF-10 shipping container involved in an accident.

The staff verified that the structural analysis scale drop test models employed foams with strengths that result in impact limiter strains and package accelerations that conservatively bound those of the actual package. To ensure the bounding nature of the structural analysis, the SAR defines an allowable range of foam compressive stress. The staff reviewed the applicant's foam test data and verified that the foam meets the required compressive strength properties. Therefore, the staff finds that the applicant has adequate controls on the foam properties to ensure that the impact limiter can fulfill its structural function.

Thermal Properties of Materials:

As described in the SAR Section 6, "Requirements Applicable to Packaging and Package," the applicant stated that it is demonstrated that the package is safely designed for the temperature range from -40°C to +70°C.

The staff evaluated the applicant's thermal properties of the materials credited in the thermal analysis and determined that the thermal properties (e.g., thermal conductivity, thermal expansion, etc.) are consistent with those in the technical literature.

*7.4.2 Brittle Fracture:*

The staff finds that the applicant has adequately considered fracture behavior in the ANF-10 package design because the austenitic stainless steels and aluminum alloys used in the package construction for impact energy absorption provide excellent fracture strength at low service temperatures.

*7.4.3 Radiation Shielding:*

As described in Section 2.5 of the SAR the applicant stated that the ANF-10 shipping container, together with the bottom section of the container, its installed components, the container lid and top end cover, forms the shielding of the packaging. In addition, due to the low dose rate, no special shielding is required to comply with the maximum allowable dose rate values on the outside of the container. The staff verified that the applicant appropriately described the density and geometry of the ANF-10 package materials, and therefore, finds the material properties used in the shielding analysis to be acceptable.

**7.5 Corrosion, Chemical Reaction and Radiation Effects:**

*7.5.1 Corrosion Resistance:*

As described in SAR Section 2 the "Description of the Design," the staff noted that the corrosion resistance of the package is achieved by the use of austenitic stainless steel cladding. The staff also noted that Section 5.2 of document ANFG-11.101 (ANF, 2014a) requires the visual inspection of package for evidence of no damages, conformity with design and cleanliness before and after each transport operation.

The staff reviewed the materials of the packaging and finds that the applicant adequately considered corrosion resistance because the ANF-10 container cladding and internal protective channels are constructed of stainless steel, which is compatible with the air environments to which the internal and external surfaces of the packaging is exposed. The staff noted that galvanic corrosion between the aluminum honeycomb and the welded stainless steel cladding is not expected because water is effectively sealed off under normal conditions of transport. The applicant stated that the accumulation of water is prevented as it can run off easily from the flat and smooth external surfaces of the container.

In addition, water inlet and outlet openings are located on all sides at the foot end of the inner protective channel and at the top end of the guide tube to enable water that has leaked into the container due to accident-induced defects to flow back out of the inner protective channels. Further, the water equalization between the inner protective channels and the inside of the container is required for reasons of criticality safety and the plastic foil is open at both ends to permit free water ingress and egress to and from the fuel assembly. The applicant stated that for shipping tubes the water runoff drill holes are located in the steel pipe, in the cover and also in the sealing plate.

Further, the periodic visual inspections of the package can identify corrosion should it arise; therefore, the staff finds no credible corrosion or other adverse reactions of the ANF-10 unirradiated-fuel package will exist during transport.

*7.5.2 Protective Coatings:*

None.

**7.6 Content Reactions:**

*7.6.1 Radiation Effects:*

None.

**7.7 Component-Specific Reviews:**

Seals:

As described in the SAR Section 2, “Description of Design,” the applicant stated that all-round seals made of expanded natural rubber are installed between the cover and the bottom section of the container and between the top end cover and bottom section of the container. The staff noted that document ANFG-11.103 (ANF, 2019b) material sheet specifies Isoprene rubber, natural rubber (NR), Styrene-butadiene rubber (SBR), Blends of NR-SBR and Polyurethane (PUR) to DIN 7726, DIN 7715, DIN 53 517, DIN EN ISO 845 and DIN EN ISO 1856 standards. The staff noted the ANF-10 container seal is used for vibration dampening during transportation and is not leak-tight tested.

The staff verified, from open literature (e.g., data sheets, handbooks, etc.), the operating temperature range for natural rubber is -40°C/+80°C. The applicant stated that following the hypothetical accident conditions fire organic materials such as the rubber gasket had undergone total combustion. In addition, Section 5.2 of document ANFG-11.101 (ANF, 2014a) requires the visual inspection of package for evidence of no damages, conformity with design and cleanliness and actions to replace and/or repair materials due to evidence of non-conformities before and after each transport operation. The staff finds the seal material to be acceptable

based on the discussion above, the staff evaluated the rubbers specified and that the seals will be periodically inspected and replaced.

Bolts/Screws/Nuts:

As described in document ANFG-11.103 (ANF, 2019b) the applicant stated that screws and nuts ($\leq$ 24) are fabricated from austenitic stainless steels in steel group A3, A4 and A5 according to DIN EN ISO 3506-1 (screws) or DIN EN ISO 3506-2 (nuts) in property classes 50 and 70. In addition, load bearing bolts are A4-70, M10. The staff finds that the applicant has adequately considered corrosion and fracture behavior in the ANF-10 package design because the austenitic stainless steel bolts/fasteners used in the package construction provide both excellent corrosion resistance during operating conditions and excellent fracture strength at low service temperatures.

Polyethylene Plates:

As described in SAR Section 2 the applicant stated that the U-shaped bottom section of the protective channel is surrounded by neutron absorbing polyethylene plates. As described in document ANFG-11.103 (ANF, 2019b) the applicant stated that this polyethylene-homopolymer (PE-HD) without fillers and reinforcing material is fabricated to DIN EN ISO 1872-1. The applicant stated that polyethylene is assumed to have a density of 0.95 g/cm$^3$, however the generic plastic shows an enveloping plastic density of 1.04 g/cm$^3$, a maximum hydrogen content of 11.8% by mass, and a maximum carbon content of 73.0% by mass. In addition, the density of the polyethylene as well as the geometric shape are varied in the analysis under hypothetical accident conditions. Further, water inclusion in the plastic is not assumed and the plastic components, nitrogen and oxygen remain conservatively ignored.

The staff verified that the applicant appropriately described the density and geometry of the ANF-10 plastic materials, and therefore, finds the material properties used in the criticality analysis to be acceptable.

## 7.8 Acceptance Tests:

Inner Protective Channels:

As described in document ANFG-11.103 (ANF, 2019b) the applicant stated the following qualification and acceptance tests for the boronized austenitic stainless steel sheets:

**Table 1: Qualification and Acceptance Tests for Boronized Austenitic Stainless Steel Sheets**

| | |
|---|---|
| Qualification: | The manufacturer must be recognized by BAM and have a certified quality assurance system (e.g., EN ISO 9001). |
| Chemical composition (wt.-%): | B 0.80 - 1.00<br>Ni permitted up to 14.0% (1). |
| Isotope distribution: | The alloying element boron must have the natural isotope distribution of B10 and B11 (19.9 At-% / 80.1 At-% ±0.5 At-%). |

| **Tests and Examinations** | |
|---|---|
| Chemical analysis of heat(s): | The manufacturer must produce a test procedure for the measuring method for Boron and submit it to the customer and BAM for approval. |
| Product analysis: | The boron content shall be demonstrated on one rolled sheet per slab (position of rolled sheets sampled statistically distributed across the slabs).<br>Additional testing of one sample per heat by a test laboratory recognized by BAM. |
| Isotope distribution: | The natural distribution of boron isotopes B10 and B11 should be demonstrated on one sample per heat.<br>Additional testing of one sample per heat by a test laboratory recognized by BAM. |
| Boron distribution in the smelts: | Uniform distribution and an adequate boron content in the heat should be demonstrated on each rolled sheet by means of a suitable measuring method (e.g., neutron absorption measurement).<br>The manufacturer must produce a test procedure for the measuring method, indicating the accuracy of measurement, and submit it to the customer and BAM for approval.<br>Requirements according to chemical composition of material sheet WB-05/ANF-10. |
| Surface condition: (On Every Strip): | Visual inspection following cleaning.<br>Check of material identity satisfied by test according to material sheet WB-05/ANF-10, “Boron distribution in the smelts.” |
| Final inspection by the customer: | Requirements according to material sheet WB-05/ANF-10, “surface condition,” and “dimensional requirements.” |
| Scope of examination: | Dimensional inspection: random samples.<br>Visual inspection: 10% (1). |

Notes:
(1) In the case of impermissible displays, the scope of examination should be increased to 25% (2).
(2) In the event of further impermissible displays within the envisaged examination scope, the scope is to be increased to 100 %.

The staff verified that the applicant appropriately described the qualification, acceptance testing and criteria of the ANF-10 boronized austenitic steel plate, and therefore, finds the acceptance testing used in the fabrication of the inner protective channel to be acceptable.

### 7.9 Evaluations Findings:

Based on the review of the statements and representations contained in the application, the staff concludes that the materials evaluations have been adequately described, and the ANF-10 package has adequate materials performance to meet the requirements of the IAEA SSR-6 (IAEA, 2012).

## 8.0 QUALITY ASSURANCE

The applicant developed and described a quality assurance (QA) program for activities associated with transportation packaging components important to safety. Those activities include design, procurement, fabrication, assembly, testing, modification, maintenance, repair, and use. The applicant's description of the QA program [i.e., management system and compliance assurance programs in IAEA SSR-6 (IAEA, 2012)] meets the requirements of the applicable IAEA SSR-6.

The staff reviewed F-AW-1167 "Management System for Quality Assurance for Types of Construction Used to Transport Dangerous Goods," Revision 0, dated October 10, 2019 and finds that this document describes quality assurance measures for compliance with 10 CFR Part 71, Subpart H.

Additionally, monitoring of the management system for the design, construction, manufacture, operation, maintenance and in-service inspections is BAM-GGR 011, "Quality Management Measures for Packaging Designs Subject to Approval for Packages for Transport of Radioactive Materials," Revision 01, dated October 01, 2018. The staff reviewed BAM-GGR 011 and noted the requirements in this document are in accordance with the IAEA SSR-6. Further, the staff finds that Container Procedure ANFG-11.101 (11E) (ANF, 2014a), is the authoritative text on handling and maintenance and that ANFG-11.101 (12E) (ANF, 2014a), controls the execution of recurring inspections on fuel assembly shipping containers.

The staff finds, with reasonable assurance, that the QA program for the ANF-10 transportation packaging:

a. meets the requirements in IAEA SSR-6 (IAEA, 2012), and

b. encompasses design controls, materials and services procurement controls, records and document controls, fabrication controls, nonconformance and corrective actions controls, an audit program, and operations or programs controls, as appropriate, adequate to ensure that the package will allow safe transport of the radioactive material authorized in this approval.

## 9.0 REFERENCES


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|---|---|
| (ANF, 2000a) | Advanced Nuclear Fuels (ANF) GmbH, B-TA-3814, "Determination of the Impact Position and Impact Angles for the Drop Tests Performed with Shipping Container ANF-10," ML19176A215. |
| (ANF, 2000b) | ANF GmbH, Calculation Report 5-021-3072-04, Rev. 0, "Verification of Local Dose Rates for the ANF-10 Shipping Container in accordance with IAEA Standards," ML19176A238. |

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|---|---|
| (ANF, 2014a) | ANF GmbH, ANFG-11.101 (11E), Rev. 8, "Container Procedure: Handling and Maintenance of BWR Fuel Assembly Shipping Containers ANF-10," ML19176A242. |
| (ANF, 2014b) | ANF GmbH, ANFG-11.101 (12E), Rev. 4, "Recurring Inspection of ANF-10 Fuel Assembly Shipping Containers," ML19176A243. |
| (ANF, 2018a) | ANF GmbH, ANFG-11.106 (05E), Rev. 2, "Safety Analysis Report ANF-10," ML19176A201. |
| (ANF, 2018b) | ANF GmbH, ANFG-5.061 (086), Rev. 2, "Criticality Safety Analysis," ML19176A236. |
| (ANF, 2018c) | ANF GmbH, ANFG-5.061 (087), Rev. 2, "Criticality Safety Analysis," ML19176A237. |
| (ANF, 2019a) | ANF GmbH, FS1-0033146, Rev. 1, "ANF-10 Shipping Container for non-irradiated BWR Fuel Assemblies Strength Verification for Load Attachment Points," ML19176A210. |
| (ANF, 2019b) | ANF GmbH, ANFG-11.103, "Manufacture of manufacturing document stated above as conforming to the German Institute of Standardization," ML19176A212. |
| (IAEA, 2012) | International Atomic Energy Agency, IAEA SSR-6, “Regulations for the Safe Transport of Radioactive Material,” 2012 Edition, https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1570_web.pdf. |
| (BAM, 1998) | German Federal Institute for Materials Research and Testing (BAM), "Test Report No. 20555 Instrumented Drop Tests Performed on the Prototype of an ANF-10 Shipping Container," ML19176A220. |
| (Siemens, 2000a) | Siemens, Work Report A1C-1306882-0, "Test Program for the Shipping Container ANF-10 for New (non-irradiated) BWR Fuel Assemblies," ML19176A214. |
| (Siemens, 2000b) | Siemens, Test Report A1C-1307671-0, "Thermal Test Performed on Six Dummy Rods with a Diameter of 10.05 mm in Accordance with the Criteria of the IAEA Thermal Test," ML19176A231. |
| (Siemens, 2000c) | Siemens, Test Report A1C-1307754-0, "Determination of Fuel Rod Surface Temperature with a Reduced-Length Test Specimen of Transport Container Under the Conditions of the IAEA Thermal Test," ML19176A232. |
| (DOT, 2019) | U.S. DOT, U.S. Department of Transportation, "Transmittal of German Certificate of Competent Authority D/4377/AF-96 (Rev. 0) for the ANF-10 package for Review," ML19176A254. |

**CONCLUSION**

Based on the statements and representations contained in the documents referenced above, and the conditions listed above, the staff concludes that the changes to the Model No. ANF-10 package meet the requirements of IAEA SSR-6 (IAEA, 2012).

Issued with letter to R. Boyle, U. S. Department of Transportation, on May13, 2020.