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

SAFETY EVALUATION REPORT
Docket No. 71-3095
Model No. ANF-10
German Certificate of Competent Authority D/4377/AF-96
Revision 1

SUMMARY

By letter dated May 26, 2023 (Agencywide Documents Access and Management System {ADAMS} Accession No. ML23297A029), the U.S. Department of Transportation (DOT) (the applicant thereafter) requested that the U.S. Nuclear Regulatory Commission (NRC) staff performed a review of the German Certificate of Approval D/4377/AF-96, Revision 1, for the Model No. ANF-10 transport package and make a recommendation concerning the revalidation of the package for import and export use.

DOT had previously issued competent authority certification (CAC) USA/0827/AF-96, Revision 0, validating the German Competent Authority Certificate D/4377/AF-96, Revision 0.

The purpose of this revalidation is a change to the licensed contents to include Framatome's BWR Type ATRIUM 11 fresh fuel assemblies to support delivery of ATRIUM 11 to European power plants. Additional changes within the application include aging management criteria, revised drawings for the rod transport tube, material designations due to revision of standards (although with no change to material properties), and a new overview about the boundary conditions for the criticality evaluation.

The NRC (the staff thereafter) reviewed the application, as supplemented, against the requirements in International Atomic Energy Agency (IAEA) Specific Safety Requirements, No. SSR-6, 2018 Edition, “Regulations for the Safe Transport of Radioactive Material,” (SSR-6). In support of this request, the following documents were provided for review:

- Reg. 01 - Safety Analysis Report: Amendment to regulation, new inventory, reference to aging management
- Reg. 05 - List of drawings: Revised drawings for the shipping tube for rod transport (no impact on transport of fuel assemblies)
- Reg. 06 - Proof for load attachment points: Amendment of material designation (no change of material properties) due to revision of standards
- Reg. 08 – Fabrication specification: Amendment to updated standards and added list of components
- Reg. 20 - Criticality Safety Analysis Report: Amendment to new inventory ATRIUM 11 with displacement of partial length rods
- Reg. 21 - Report for boundary conditions criticality safety analysis: Amendment to new inventory
- Reg. 31 - Aging management report: New document to specify the aging management.

Enclosure

Based upon the NRC review of the statements and representations contained in the documents listed above, and for the reasons stated in this safety evaluation report (SER), the NRC recommends revalidation of the German Certificate of Competent Authority D/4377/AF-96, Revision 1, for the Model No. ANF-10 package with no additional conditions.

1.0 GENERAL INFORMATION

The newly authorized contents for the Model No. ANF-10 package have the following characteristics:

Type	ATRIUM 11
Channel	Channeled
Enrichment	Max. 5.0 Mass.-%
Internal pressure (25°C)	Max. 0.6 MPa
Number fuel rods	112 (20 partial length)
Active length	Max. 3900 mm
Pitch	11.35 – 12.85 mm
Diameter pellets	Max. 8.2 mm
Diameter cladding tube	Max. 9.3 mm
Gd-Rods	Not considered
Maximum Weight	320 kg (705 lbs)

2.0 STRUCTURAL EVALUATION

The structural evaluation of the ANF-10 package is not changed from the initial Rev. 0 review. Based on a review of the statements and representations in the application, the staff concludes that the ANF-10 package has sufficient structural capacity to meet the requirements of IAEA SSR-6.

3.0 THERMAL EVALUATION

The thermal evaluation of the ANF-10 package is not changed from the initial Rev. 0 review. Based on review of the statements and representations in the application, the NRC staff finds that the ANF-10 transportation package has been adequately described and evaluated to demonstrate that it satisfies the thermal requirements of SSR-6.

4.0 CONTAINMENT EVALUATION

The containment evaluation of the ANF-10 package is not changed from the initial Rev. 0 review. Based on review of the statements and representations in the application, the NRC staff finds that the ANF-10 transportation package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of SSR-6.

6.0 CRITICALITY EVALUATION

The criticality evaluation of the ANF-10 package has changed from the initial Rev. 0 review in that the applicant has requested the addition of ATRIUM 11 channeled fuel to the authorized contents. The ANF-10 shipping package can contain up to two unirradiated ATRIUM 11x11 BWR channeled fuel assemblies, with an allowance of up to 20 partial length fuel rods and has a maximum enrichment of 5.0 wt.% ^{235}U. Staff reviewed the information provided to DOT by Framatome in its application and its supplements against the regulatory requirements of IAEA SSR-6, 2018 Edition.

6.1 Description of Criticality Design

Up to two ATRIUM 11 fuel assemblies with fuel channels are placed in the inner protective boxes of the ANF-10 shipping containers that are constructed of 3 mm borated steel with a minimum boron content of 0.8%. Polyethylene and Etafoam (which is a composite foam) panels are used for vibration control during shipment, and plastic shipping restraints are inside the ANF-10.

6.2 Nuclear Fuel Contents

Only non-irradiated fresh fuel assemblies are allowed in the ANF-10 transportation package under this revalidation. As described in the SAR Section 3.3.1, the contents of the ANF-10 package are limited to a maximum of two non-irradiated fuel assemblies with enriched uranium consisting of full-length fuel rods and partial length fuel rods. Each fuel rod contains UO_2 pellets and Gd_2O_3/UO_2 pellets with a maximum ^{235}U enrichment of 5.00 wt.% with a zirconium alloy cladding and a maximum active length of 3900.0 mm. Specific fuel data are specified in Table 1 of the applicant's criticality safety analysis [ref. ANFG-5.061 (086), Rev. 6]. The fuel assembly channel has an internal maximum width of 136.8 mm. Up to 20 partial length ATRUIM 11 fuel rods are allowed in the ANF-10 transportation package, which consist of eight longer rods and twelve shorter rods as shown in Figure 1 of the criticality safety analysis. The maximum active length of the longer partial length fuel rods is 3000.0 mm, and the maximum active length of the shorter partial length fuel rods is 2000.0 mm. The central water channel has a cross section that fills nine fuel rod positions.

6.3 General Considerations for Criticality Safety

The applicant provided analyses for evaluating a single package, arrays of packages under normal condition of transport, and arrays of packages under hypothetical accident conditions for the ANF-10 fresh fuel package with ATRIUM 11 fuel assemblies.

The applicant used computer modeling of the system using the SCALE 6.2.4 code package with the 252-group ENDF/B-VII cross section library and created models that were consistent with the loaded package design, including tolerances and material specification of package components that would maximize reactivity. The UO_2 pellets are modeled as cylinder with a theoretical density of 10.96 g/cm3. Any neutron poisons that may be present in a fuel rod (e.g., Gd_2O_3) are conservatively ignored in the model since they would reduce overall reactivity of the fuel rod. The applicant also evaluated any potential deviations from the minimal design configurations as well as flooding and full water reflection of the loaded ANF-10 package.

6.4 Demonstration of Maximum Reactivity

Under the requirements of IAEA SSR-6, a transportation package is required to remain subcritical under routine transport conditions, normal transport conditions, and accident transport conditions. The applicant evaluated various configurations of the ANF-10 package loaded with ATRIUM 11 BWR fuel assemblies using full water interstitial moderation and 300 mm water reflection on all sides. Fuel pin spacing was varied to account for any shifting due to hypothetical accident conditions, pellet diameter, and the thickness of the cladding. In all instances, the k_{eff} increased with increased fuel rod pitch, and the highest k_{eff} was when the cladding thickness was minimized and with a reduced fuel rod diameter, which is shown in Tables 3 through 6 of the criticality safety analysis. In addition, the applicant also evaluated the moderation effects of the plastic and foam contents, with the highest k_{eff} being bounded by polyethylene. Staff finds that the applicant used conservative assumptions and modeling techniques that are appropriate for this transportation package and its new contents.

For normal conditions of transport, the applicant calculated a CSI of 7.2, which would allow up to 35 ANF-10 packages loaded with ATRIUM 11 fuel to be transported per conveyance. Staff confirmed this calculation. The maximum k_{eff} for ATRIUM 11 fuel assemblies was determined by the applicant to be 0.89711 ± 0.00025, which occurred with a pellet diameter of 8.2 mm and a cladding tub outer diameter of 9.3 mm under flooded conditions. For hypothetical accident conditions, the applicant evaluated the maximum k_{eff} assuming a 3x5 array of packages moderated by polyethylene (which was found to be the bounding moderator) and determined that the maximum k_{eff} to be 0.93405 ± 0.00028. Staff reviewed the applicant's analysis for ATRIUM 11 fuel in the ANF-10 transportation package and developed independent calculational models for both the normal conditions of transport and hypothetical accident conditions that confirm the applicant's analysis and methodology. Therefore, based on the applicant's use of conservative assumptions, appropriate modeling techniques, and staff's independent analysis, staff finds that the results of ANF-10 package loaded with fresh ATRIUM 11 fuel assemblies are acceptable for transportation.

6.5 Evaluation Findings

The staff finds that the proposed addition of two ATRIUM 11 BWR fuel assemblies with a maximum enrichment of 5.0% ^{235}U will remain subcritical for all routine, normal, and hypothetical accident conditions for transport for the contents specified in the Certificate of Approval D/4377/AF-96, Revision 1. Staff based its finding on the contents of the applicant's criticality safety analysis, verification of adequate system modeling that was performed by the applicant, and staff independent confirmatory analysis. This revision maintains the maximum k_{eff} acceptance standard for all analyzed conditions and scenarios and meets the requirement that the package maintain subcriticality under all conditions of routine, normal, and hypothetical accident conditions as required by SSR-6, 2018 edition, Paragraphs 673(a) and 682.

7.0 MATERIALS EVALUATION

Scope of Revalidation:

The staff reviewed the information provided to the DOT by Framatome in its application and its supplements against the regulatory requirements of IAEA SSR-6, 2018 Edition. The staff also reviewed the proposed changes to the package described below.

Proposed Changes:

The applicant stated that the reason for the revision was based on the following:

- Change of licensed inventory from SVEA-96L or SVEA-96 Otima 2 to ATRIUM 11 BWR fuel design (channeled)
- Revised drawings for shipping tube for rod transport
- Proof for load attachment points: Amendment of material designation (no change of material properties) due to revision of standards
- Report for boundary conditions criticality safety analysis: new document to describe and specify the boundary conditions for criticality safety analysis
- Aging management report: new document to specify the aging management process

Review Criteria:

The ANF-10 shipping package is designed to transport unirradiated BWR fuel assemblies (ATRIUM 11x11 design). The staff conducted a revalidation review for the German Competent Authority Certificate Number D/4377/AF-96, Revision 1, Model No. ANF-10, Type A(F) package, per the requirements in Section VI of the IAEA SSR-6. The pertinent IAEA SSR-6 requirements are listed below:

613. The package shall be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under routine conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole. In particular, nuts, bolts, and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.

613A. The design of the package shall take into account aging mechanisms.

614. The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behavior under irradiation.

616. The design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport.

639. The design of the package shall take into account temperatures ranging from 40 °C to +70 °C for the components of the packaging. Attention shall be given to freezing temperatures for liquids and to the potential degradation of packaging materials within the given temperature range.

640. The design and manufacturing techniques shall be in accordance with national or international standards, or other requirements, acceptable to the competent authority.

644. The design of any component of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.

648. A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent:

a) Loss or dispersal of the radioactive contents;
b) More than a 20% increase in the maximum dose rate at any external surface of the package.

673. Fissile material shall be transported so as to:

a) Maintain subcriticality during routine, normal and accident conditions of transport; in particular, the following contingencies shall be considered:
    I. Leakage of water into or out of packages;
    II. Loss of efficiency of built-in neutron absorbers or moderators;
    III. Rearrangement of the contents either within the package or as a result of loss from the package;
    IV. Reduction of spaces within or between packages;
    V. Packages becoming immersed in water or buried in snow;
    VI. Temperature changes.
b) Meet the requirements:
    I. Of para. 636 except for unpackaged material when specifically allowed by para. 417(e);
    II. Prescribed elsewhere in these Regulations that pertain to the radioactive properties of the material;
    III. Of para. 637 unless the material is excepted by para. 417;
    IV. Of paras 676-686, unless the material is excepted by para. 417, 674 or 675.

679. The package shall be designed for an ambient temperature range of -40 °C to +38 °C unless the competent authority specifies otherwise in the certificate of approval for the package design.

682. The package shall be subcritical under the conditions of paras 680 and 681 and with the package conditions that result in the maximum neutron multiplication consistent with:

(a) Routine conditions of transport (incident free);
(b) The tests specified in para. 684(b);
(c) The tests specified in para. 685(b).

726. The specimen shall be subjected to the cumulative effects of the tests specified in paras 727 and 728, in that order. Following these tests, either this specimen or a separate specimen shall be subjected to the effect(s) of the water immersion test(s), as specified in para. 729 and, if applicable, para. 730

728. Thermal test: The specimen shall be in thermal equilibrium under conditions of an ambient temperature of 38 °C, subject to the solar insolation conditions specified in Table 12 and subject to the design maximum rate of internal heat generation within the package from the radioactive contents. Alternatively, any of these parameters are allowed to have different values prior to, and during, the test, provided due account is taken of them in the subsequent assessment of package response. The thermal test shall then consist of (a) followed by (b).

(a) Exposure of a specimen for a period of 30 min to a thermal environment that provides a heat flux at least equivalent to that of a hydrocarbon fuel–air fire in sufficiently quiescent ambient conditions to give a minimum average flame emissivity coefficient of 0.9 and an average temperature of at least 800 °C, fully engulfing the specimen, with a surface absorptivity coefficient of 0.8 or that value that the package may be demonstrated to possess if exposed to the fire specified.

(b) Exposure of the specimen to an ambient temperature of 38 °C, subject to the solar insolation conditions specified in Table 12 and subject to the design maximum rate of internal heat generation within the package by the radioactive contents for a sufficient period to ensure that temperatures in the specimen are decreasing in all parts of the specimen and/or are approaching initial steady state conditions. Alternatively, any of these parameters are allowed to have different values following cessation of heating, provided due account is taken of them in the subsequent assessment of package response. During and following the test, the specimen shall not be artificially cooled and any combustion of materials of the specimen shall be permitted to proceed naturally.

7.1 Package Description:

7.1.1 Container

As described in the SAR Section 2.1, “Description of the Design,” the applicant stated that all container components are constructed of multiple layers of 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.

In addition, the top end cover is fastened using austenitic stainless-steel Group A3/A4/A5 screws (DIN EN ISO 3506-1) onto the bottom section of the container and the container lid. Further, an austenitic steel square guide tube (DIN 10217-7, 10219-1, and 10219-2) is bolted onto the top end cover by an adapter plate, which protects the fuel assembly.

7.1.2 Inner Protective Boxes:

As described in the SAR Section 2.1.3, “Description of Inner Protective Boxes,” one BWR fuel assembly with fuel assembly channel can be inserted on either side of the central divider in the container bottom. In addition, the inner protective boxes 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. Further, the fuel assemblies have different lengths and 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 polyoxymethylene (POM).

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 ATRIUM with enriched uranium consisting of full-length fuel rods and partial length fuel rods. In addition, the rods contain uranium oxide pellets and gadolinium oxide/uranium oxide pellets with a U-235 enrichment of 5.00 wt.% maximum. Further, the pellets are enclosed in zirconium alloy (Zry-2, Zry-2 Liner, Zry-2-0.4 FE Liner, or LTP-2) cladding. The applicant stated that the fuel rods form the fuel assembly together with the fuel assembly structure (i.e., spacers, water channel, upper and lower tie plates).

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 and the number of rods is limited by the tube capacity. The applicant stated that no bottom end adapters are utilized in the inner protective boxes when the shipping container is used for transporting fuel rods within the shipping tubes. The shipping tubes are both axially and radially secured in the inner protective boxes.

7.2 Drawings:

The staff reviewed the package description as described above, the package drawings, SAR, and associated document ANFG-11.103 (001E, Revision 5) 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 and are specified in Table 1 of document ANF, "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.

Based on the evaluation above, the staff finds that the drawings contain sufficient information to describe the design and manufacture of the package, and the package meets the requirements in paragraph 640 of IAEA SSR-6.

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 aluminum honeycomb conform to material standard SAE AMS-A-81596A and DIN standard 29978/LN 29975, respectively. The applicant stated that the manufacturer must have a certified quality assurance system (conforming to DIN EN ISO 9001 or ASME Code Section III NCA-3800 and NCA-3900). 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.

The applicant stated that the container cover is bolted to the container bottom and the head cover, with a rubber seal placed between the flanges to ensure leak-tightness. The bolts are tightened in accordance with "Container Instructions, Handling and Maintenance of BWR fuel assembly shipping containers ANF-10" ANFG-11.101(11E), ensuring that they do not become loose during normal transport. The bolt material A4-70 properties are confirmed in FS1-

0033136, “ANF-10 Shipping Container for non-irradiated BWR Fuel Assemblies – Strength Verification for Load Attachment Point” and FS1-0030541, “Finite element calculation of the ANF-10 transport container load attachment points for boiling water reactor fuel assemblies”. Acceleration tests were performed on the container up to five times gravity as described in BAM Examination Certificate, No.: 3/20708, (September 14, 2000), with no adverse effects identified on the container cover, bottom, head cover, or inner protective box. The staff reviewed the container handling instructions and maintenance, the strength verification test, finite element (FE) calculation, and acceleration tests and finds that the bolts are capable of withstanding the effects of acceleration, vibration or vibration resonance that may arise under routine conditions of transport without deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and therefore meets the requirements of paragraph 613 of IAEA SSR-6.

7.3.2 Aging Management Plan

The staff reviewed the document ANFG-11.124 (01), Revision 2, which detailed the applicant’s consideration of aging mechanisms in the design phase and the aging surveillance program, which describe the maintenance, inspections and procedures for the ANF-10 shipping container.

In SAR Section 7.4, “Determination of influencing parameters,” the applicant evaluated the aging mechanisms, including environment, handling, design, and inventory.

<u>Environment</u>:

The applicant evaluated the effect of different ambient temperatures and its aging effects with respect to strength and material embrittlement. The evaluation noted that the shipping container is approved for the temperature range from −40°C to 100°C and in the strength calculation, the load bearing parts have been verified for 100°C. The applicant also noted that a characteristic of austenitic steels is that as temperature drops, strength actually increases, while also demonstrating high ductility at low temperatures, therefore covering the required temperature range. The staff reviewed the applicant’s evaluation of temperature and found that the load bearing parts can withstand 100°C per the strength analysis performed in ANFG-11.105 (06E), and that austenitic steel increases in strength at lower temperatures. Therefore, staff finds that the package is qualified for the −40 to 100°C temperature range.

The applicant evaluated the effect of moisture exposure from rain, condensation water and salt water during transport. The evaluation noted that the design of the outer contour of the shipping container prevents water from accumulating. Also, the shipping container will be located in a dry environment most of the time. Only in the case of sea transport will the container be exposed to rain and salt water. The austenitic stainless steel resists moisture and due to the circumferential lid seals, moisture is not expected to enter the interior of the container. The staff reviewed the applicant’s evaluation of moisture effects and found that per SAR Table 2, “Estimated time periods of the individual operational conditions,” 91% of the time the container would be located in a “Hall environment,” which is an indoor facility protected from UV exposure with a low moisture content and at room temperature, per the classification in Table 1, “Environment and assessment of the environmental effects”. The staff reviewed drawings of the shipping container and confirmed that the shape of the shipping container would resist water accumulation while in transport.

The applicant evaluated the effect of UV radiation and its aging effects on strength and embrittlement, which stated that due to the austenitic steel outer surface it has good UV resistance. In addition, the shipping container will largely be located indoors and not exposed to UV radiation while not in active transport. The staff reviewed the applicant's evaluation of UV radiation on the shipping container and found that per SAR Table 2, "Estimated time periods of the individual operational conditions", 91% of the time the container would be in the Hall environment which has no UV radiation exposure and that austenitic stainless steel fabricated to DIN EN 10088-2 resist UV radiation.

The applicant evaluated the biological aging effects from living organisms such as small animals, insects, microorganisms, or vegetation and stated that biological effects are ruled out by storing the shipping containers in controlled halls and through regular monitoring. The staff reviewed the applicant's evaluation of biological aging effects and found that the shipping containers primarily sit in a dry and temperature-controlled environment and go through regular monitoring including visual inspections per Table 4, "Tests and Procedures for the ANF-10," and Table 5, "Aging Surveillance Program (ASP)," before every transport.

The applicant evaluated the aging effects of the various media the shipping container is brought in contact with which could trigger corrosion and embrittlement. The evaluation included salt water, distilled water, isopropanol, 3M™ industrial citrus cleaner, and Loctite® 243. For salt water, the contact would only occur during transport by sea, but the austenitic stainless steel would resist corrosion. Distilled water for the cleaning of components and the stainless steel and polymers would not have any aging effects. The 3M™ industrial citrus cleaner used to loosen labels on the outer container does not affect stainless steel. The Loctite® 243 used to secure bolted connections and is compatible with the packaging materials. The staff reviewed the applicant's evaluation of the aging effects of various media the shipping container is brought into contact with and found none of the media identified, including salt water, distilled water, isopropanol, 3M™ industrial citrus cleaner, and Loctite® 243 have any appreciable effects on the aging of the austenitic stainless-steel surface.

<u>Handling</u>:

The applicant evaluated static load related aging mechanisms such as material fatigue or relaxation, plastic deformation, or changes in joints. The evaluation included the shipping container, inner protective box, and the screws and threaded inserts. The static load on the shipping container due to lashing during transport is a maximum of five times its own weight, but this is insignificant in relation to the design and construction of the ANF-10 shipping container, or loads experienced during the drop tests. The staff reviewed the applicant's evaluation of aging effects due to static loads and found that package is designed and constructed to handle the static loads as a result of lashing during transport and the static loads are small with respect to the impact loading experienced by the packaging during drop tests.

The applicant evaluated dynamic load related aging mechanisms such as material wear or material fatigue. The evaluation stated that crane handling operations place the load attaching points under dynamic load and, the shipping container can experience up to a maximum of 5g dynamic load. The loading attaching points are rated to KTA 3905, "Load Attachment Points on Loads in Nuclear Power Plants" and are maintained in defined cycles. The applicant stated that the dynamic loads on the shipping container is not significant in relation to the design and construction of the ANF-10 shipping container as a whole and as the ANF-10 shipping container passed the drop tests, there is no significant contribution from dynamic loads to aging of the ANF-10 shipping container. The staff reviewed the applicant's evaluation of aging effects due to dynamic loads and found that the package is designed and constructed to handle the dynamic loads as a result of crane handling operations and the dynamic loads experienced during transport, as the load attachment points are maintained in defined cycles and the dynamic loads from transport are small in comparison to the design and construction of the ANF-10 container.

The applicant evaluated friction related aging mechanisms such as changes in components or coatings. The evaluation stated that handling operations expose loading attaching points, the shipping container, and bolts, nuts, and threaded inserts to friction during transport. Loading attaching points are maintained in defined cycles and bolts, nuts, and threaded inserts are managed and replaced based on criteria in the aging surveillance program. The staff reviewed the applicant's evaluation of aging effects due to friction and found that by managing and replacing bolts, nuts, and threaded inserts through the aging surveillance program, the effects of friction are adequately managed.

Design:

The applicant evaluated different material pairings that could trigger aging mechanisms and the evaluation found that pairing aluminum and stainless steel can cause minor corrosion, although the stainless steel is passivated, and the aluminum honeycombs are coated to prevent corrosion. The staff reviewed the applicant's evaluation of different material pairing and found that the coating of the aluminum honeycombs and passivation of the stainless steel would adequately manage galvanic corrosion.

The applicant evaluated pressurization of components that could trigger aging mechanisms such as creep or material fatigue and found that the ethylene propylene diene monomer (EPDM) seals are permanently pressurized by tightening torques of the fittings and are inspected in defined cycles and replaced as necessary under the aging surveillance program. The staff reviewed the applicant's evaluation of aging effects due to pressurization and found the applicant's management of the EPDM seals using the aging surveillance program to be acceptable.

The applicant evaluated the aging effects due to compaction of components and stated that the ANF-10 design does not contain any components that were joined by means of compaction. The staff reviewed the applicant's evaluation of aging effects due to compaction and find that as no components were joined by means of compaction, there are no aging effects due to compaction.

Inventory:

The applicant evaluated the aging effects of radiation, such as embrittlement of metals due to hydrogen deposition and found that although the inventory emits a low dose to the environment, the dose rate does not adversely affect the materials. The staff reviewed the applicant's evaluation of the aging effects of radiation, fission product, and radiolysis and found that the unirradiated fuel transported emits a low dose rate that does not adversely affect the fuel and per SAR Table 2, the inventory is present in the container for only 12% of the total life span, therefore aging effects of radiation, fission product, and radiolysis are managed.

The applicant evaluated the aging effects of the thermal load of the inventory and found that no relevant thermal load is generated by the inventory. The staff reviewed the applicant's evaluation of the aging effects of the thermal load of the inventory and found that the unirradiated inventory to be stored in the shipping container does not generate an appreciable thermal load.

The staff reviewed the applicant's evaluation of the aforementioned aging mechanisms at the design phase and found that per IAEA SSG-26, Paragraph 613A.1, the applicant properly evaluated the potential degradation phenomena over time, such as corrosion, abrasion, fatigue, crack propagation, changes of material compositions or mechanical properties due to thermal loadings or radiation, generation of decomposition gases and the impact of these phenomena on performance of safety functions.

<u>Aging Surveillance Program</u>:

The applicant categorized the intervals by categories A through E, with A through C occurring before every transport, and D every three years or 15th transport, and E every six years or 60th transport. Visual inspections are the primary measures taken for categories A through C and look to identify any damage to components and replacement of any defective components. Non-destructive tests are the primary measures for categories D and E, with dye penetrant testing on the load attaching points and replacement of screws of the load attaching points. The applicant described in Table 5 of ANFG-11.124 the individual components considered for aging, the related drawings, component classification, the material, replaceability/accessibility, the assessment with respect to aging, the interval category, and the measures taken. Any deviations found during surveillance are documented and archived in the logbook of the shipping container per F-AW 1167, "Management system for Quality Assurance for Design Types Used to Transport Dangerous Goods, Management System" and the handling procedure ANFG 11.101 (11), "Container procedure Handling and maintenance of ANF-10 BWR fuel assembly shipping containers". The staff reviewed the analysis of the aging mechanisms and confirmed that the package meets the requirements of 613A.

7.3.3 Weld Design and Inspection:

As described in the SAR and document ANFG-11.103 (001E, Revision 5) welding is performed per DIN EN 1011, DIN EN ISO 15609, 15613, and 15614-1 for using welders that are qualified per DIN EN ISO 9606-1, "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 with the German construction code.

Based on the evaluation above, the staff finds that the manufacture of the package is in accordance with applicable standards, and the package meets the requirements in paragraphs 640 and 648 of IAEA SSR-6.

7.4 Mechanical Properties:

The staff noted that the applicant provided mechanical properties 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 (001E, Revision 5) the applicant stated that the mechanical properties of the Types 304L, 321, 347 and 316 stainless steels acceptable for use in fabrication of the cladding for the ANF-10 container, which 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 EN 10219-2, “Cold formed welded structural steel hollow sections - Part 2: Limit allowances, dimensions and statical values.” The staff reviewed the temperature-dependent mechanical properties used in the applicant’s mechanical calculations and confirmed that the properties are consistent with those in the DIN EN standards stated above.

Non-ferrous:

As described in the SAR and document ANFG-11.103 (001E, Revision 5) 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 fabrications of the honeycomb cores were obtained from SAE AMS-A-81596A, “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 in the DIN LN and SAE standard stated above.

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 inner protective boxes are surrounded by sections of polyethylene and composite foam plates, which provide shock absorption. As described in document ANFG-11.103 (001E, Revision 5) the applicant stated that the polyethylene is fabricated to DIN EN ISO 14632 and DIN EN ISO 17855-1, and the composite foam plates to DIN EN ISO 472, DIN EN ISO 472/A1, DIN EN ISO 815-1, DIN EN ISO 815-2, DIN EN ISO 845, 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 (Etaphoam) 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. 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.

Based on the evaluations above, the staff finds that the mechanical properties of materials used in the structural analysis are consistent with applicable standards and values in the technical literature, and the package meets the requirements in paragraphs 616, 639, 640, 648, and 679 of the IAEA SSR-6.

Thermal Properties of Materials:

As described in the SAR Section 6, "Requirements for Packagings and Packages," the applicant stated that it is demonstrated that the package is safely designed for the temperature range from -40°C to +70°C. The applicant based this on characteristic strength values increasing for austenitic steels as temperatures drop, so that the results of the calculated verification covers the entire temperature range. 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.

Based on the evaluations above, the staff finds that the thermal properties of materials used in the thermal analysis are acceptable, and the package meets the requirements in paragraphs 616, 639, and 640 of IAEA SSR-6.

7.4.1 Brittle Fracture:

The applicant detailed the mechanical design of the ANF-10 shipping container, which consists of an austenitic steel plate outer skin, an energy-absorbing intermediate layer of aluminum honeycombs and an inner protective casing which holds the fuel assemblies. In IABG-Report: B-TA-3814, "Determination of the impact position and impact angles for the drop tests performed with shipping container ANF-10," Table 1: Material parameters applied for the austenitic steel plates and aluminum sheets, the applicant and Table 2: Material parameters applied for the aluminum honeycombs and the PU foam, the applicant specifies the material properties at the required temperature range of the shipping container. The properties demonstrated high ductility at low temperatures especially for austenitic steels, which increases as temperatures drop. 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 acceptable fracture strength at low service temperatures.

7.4.2 Radiation Shielding:

As described in Section 2.5 of the SAR the applicant stated that the ANF-10 shipping container, together with the container bottom and internals as well as the container cover and head 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.

7.4.3 Criticality Control:

The applicant stated that sufficient sub-criticality under routine, normal and accident shipping conditions was verified in the Criticality Safety Analysis for ANF-10, ANFG-5.061 (086), Revision 6. The staff reviewed the Criticality Safety Analysis and found that it demonstrated the subcriticality of the ATRIUM 11 BWR fuel type with CSI value of 7.2 and effective neutron multiplication factor less than 0.95 for the ANF-10 shipping container.

The applicant stated that the thermal test was performed in a laboratory furnace per "Thermal test performed on six dummy rods with a diameter of 10.05mm in accordance with the criteria of the IAEA thermal test, Test Report: A1C-1307671" where the clad surface temperature was kept to at least 800 °C for a period of 30 minutes. Determination of the surface temperature of the fuel rods was completed per, "Determination of fuel rod surface temperature with a reduced-length test specimen of transport container ANF-10 under the conditions of the IAEA thermal test, Test Report: A1C-1307754". The thermal test report concluded that no bulging of the cladding tubes occurred, nor loss of integrity as a result of the test and therefore no effects with respect to criticality. The staff reviewed the thermal test reports and verified that the applicant had demonstrated compliance with the thermal test requirement paragraph 728 of IAEA SSR-6.

Based on the evaluations above, the staff finds that the properties of the neutron absorbing materials used in the criticality analysis are acceptable, and the package meets the requirements in paragraphs 673, 682, and 728 of IAEA SSR-6.

7.5 Corrosion Resistance:

As described in SAR Section 2.1 the "Description of the Design," the staff noted that the corrosion resistance of the package is achieved by the use of austenitic stainless-steel sheets (cladding). The staff also noted that Section 5.2 of document ANFG-11.101 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 boxes 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 due to the design of the outer contour of the shipping container.

In addition, water inlet and outlet openings are located on all sides at the bottom end of the inner protective box 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 boxes.

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.

Based on the evaluations above, the staff finds that the package design, inspections, and maintenance activities adequately prevent adverse reactions that may affect the ability of the package to perform its safety functions, and the package meets the requirements in Paragraphs 614 and 644 of IAEA SSR-6.

7.6 Bolts/Screws/Nuts:

As described in document ANFG-11.103 (001E, Revision 5) the applicant stated that screws and nuts (< 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 strength grades 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 the required corrosion resistance during operating conditions and the required fracture strength at low service temperatures.

7.7 Content Integrity:

In SAR Section 8.2.5, “Tests for Demonstrating the Ability to Withstand Accident Transport Conditions”, the applicant described the mechanical drop tests performed on the ANF-10 transport package. The drop tests were performed in accordance with “Test program for the Shipping Container ANF-10 for new (non-irradiated) BWR fuel assemblies, Work Report: A1C-1306882.” Measurements after the drop tests of the container and dummy assemblies with fuel channels were documented in “Measurement results for FA Shipping Container ANF-10 (Prototype1) before / after the IAEA Drop tests, (4) MEC20-A166-U993.” The IABG-Report: B-TA-3814, “Determination of the impact position and impact angles for the drop tests performed with shipping container ANF-10, evaluated the deformation and damage to the container as well as effects to the fuel assemblies. The applicant stated that the effects of the vertical drop test on the actual fuel assembly are governed by the effect of the mass of the fuel rods, which are restrained by frictional forces in the spacer cells and can only move in an axial direction relative to the fuel assembly structure. The zirconium alloy fuel rod cladding tubes exhibit high ductility and resist brittle fracture. The BAM Report No. 1.24/255, Drop tests of two dummy fuel rods of the KWO type, April 9, 1974, demonstrated that under the largest accelerations, no fuel rod leaks arose during the horizontal and vertical drop tests from a height of 9m with the fuel rods at 40 °C. Also, the volume nor distances for criticality assessment changes to any unallowable degree and adequate margin was maintained in both normal and accident transport conditions. The staff reviewed the drop test program report, the measurement results for the FA shipping container, and the evaluation of the deformation and damage to the container and the fuel assemblies and determined that the fuel cladding is capable of maintaining the fuel in its analyzed configuration of transport.

Based on the staff’s review of the mechanical tests of the packaging and fuel contents, the staff finds that the package meets the requirements of paragraphs 673, 682, and 726 of IAEA SSR-6.

7.8 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, 2018 Edition.

8.0 OPERATING PROCEDURES

The staff reviewed the description of the operating procedures for the Model No. ANF-10 package against the standards in the IAEA SSR-6. The package handling procedures in the safety analysis report include sections on package acceptance, loading, unloading, and pre- and post-shipment requirements.

9.0 MAINTENANCE PROGRAM

The staff reviewed the description of the maintenance program for the Model No. ANF-10 package against the standards in the IAEA SSR-6.

CONCLUSION

Based on the statements and representations contained in the documents referenced in this evaluation, the staff concludes that the Model No. ANF-10 package meets the requirements of the IAEA SSR-6, 2018 Edition.

Issued with letter to Richard W. Boyle, U.S. Department of Transportation,
dated November 27, 2023.