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

July 25, 2019

Mr. Franz Hilbert
DAHER NUCLEAR
TECHNOLOGIES GmbH
Margarete-von-Wrangell-Straße 7
D-63457 Hanau – GERMANY

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9362, REVISION NO. 0, FOR THE MODEL NO. DN30 PACKAGE

Dear Mr. Hilbert:

As requested by your application dated August 2, 2018, supplemented July 19, 2019, enclosed is Certificate of Compliance No. 9362, Revision No. 0, for the Model No. DN30 package. The U.S. Nuclear Regulatory Commission (NRC) staff (the staff's) safety evaluation report is also enclosed.

Daher Nuclear Technologies, GmbH, has been registered as a user of the package under the general license provisions of Title 10 of the *Code of Federal Regulations* 10 CFR 71.17 or 49 CFR 173.471. The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact Pierre Saverot of my staff at (301) 415-7505.

Sincerely,

/RA/

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

Docket No.: 71-9362
EPID: L-2018-NEW-0003

Enclosures:
1. CoC No. 9362, Rev. No. 0
2. Safety Evaluation Report

cc w/encls. 1&2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy, c/o L. Gelder

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9362, REVISION NO. 0, FOR THE MODEL NO. DN30 PACKAGE, DOCUMENT DATE: July 25, 2019

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SAFETY EVALUATION REPORT

Model No. DN30 Package
Certificate of Compliance No. 9362
Revision No. 0

SUMMARY

By letter dated August 2, 2018, Daher Nuclear Technologies, GmbH, (DNT) submitted an application for Certificate of Compliance No. 9362, Revision No. 0, for the Model No. DN30 package. The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) issued a request for supplemental information dated September 29, 2018, for which responses were received on October 4, 2018. On June 19, 2019, DNT responded to staff's request for additional information letter dated March 7, 2019. On July 19, 2019, DNT provided a consolidated application, "Safety Analysis Report of the DN30 Package, 0023-BSH-2016-002- Rev. 1", dated July 12, 2019, which supersedes Revision No. 0 of the application.

The DN30 packaging consists of the protective structural packaging (PSP) and the 30B uranium hexafluoride (UF_6) cylinder as specified in ANSI N14.1.

The DN30 PSP is a right circular cylinder constructed of two austenitic stainless steel shells: (i) the bottom half with integrated feet, a valve protecting device, a plug protecting device, two rotation preventing devices, the upper part of the closure system (consisting of six devices), and handling attachment points, and (ii) the top half with the lower part of the closure system and integrated handling attachment points for the top half. For both the bottom and top halves of the PSP, the cavity between the inner and outer shells and the flange is filled with a polyisocyanurate rigid (PIR) foam with a layer of 10 mm thermal insulation between the inner shell and the foam. All the surfaces of the inner shell of both the top and bottom halves are covered with a layer of intumescent material.

The valve protecting device, enclosing the valve of the 30B cylinder, and connected to the bottom half of the DN30 PSP by two hinges, consists of a casing of stainless steel filled with PIR foam and a protective housing with its inner walls covered with an intumescent material. The two rotation protecting devices, welded at the sides of the inner flange of the bottom half of the PSP, are identical and consist of a pin, withdrawn into the flange during loading, and inserted, during transport, into the two holes in the skirt of the 30B cylinder.

The plug protecting device is welded to the inner shell of the bottom half of the PSP and allows the plug to move in the axial direction without making contact with any part of the PSP. An elastomeric gasket, installed in the flange of the top half, prevents water inleakage during normal conditions of transport.

The PSP has a nominal length of 2,437 mm, a nominal external diameter of 1,216 mm, and a nominal height of 1,329 mm. The nominal gross weight of the package is 4,012 kg.

The 30B Cylinder, described in ANSI N14.1, is 2,070 mm long with a nominal diameter of 760 mm and a nominal wall thickness of 13 mm.

NRC staff reviewed the application using the guidance in NUREG-1609 "Standard Review Plan for Transportation Packages for Radioactive Material". The analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, and criticality protection under normal and accident conditions.

Based on the statements and representations in the application, and the conditions listed in the Certificate of Compliance, the staff concludes that the package meets the requirements of 10 CFR Part 71.

References

Safety Analysis Report of the DN30 Package, 0023-BSH-2016-002- Rev. 1, dated July 12, 2019

1.0 GENERAL INFORMATION

1.1 Packaging

The DN30 packaging consists of the DN30 Protective Structural Packaging (PSP) and the 30B cylinder specified in ANSI N14.1.

The main packaging components are the 30B cylinder with its valve and plug, the bottom half with two feet welded to the outer structure for tie-down during transport, the top half with two handling attachment points for handling of the top half, the valve protecting device attached to the bottom half by hinges, the plug protecting device mounted in the bottom half, and the rotation preventing devices consisting of two pins mounted in the bottom half.

The two halves of the DN30 PSP are connected with a 6 mortise-and-tenon system. When closed, the two halves are connected by a pin which is secured by a bolt. The design of the mortise-and-tenon system is such that neither the connecting pin nor the securing bolt are exposed to structural impacts.

The valve protecting device, enclosing the valve of the 30B cylinder during transport, consists of a stainless-steel housing filled with PIR foam. It prevents contact of the valve with any part of the PSP, or any other part the 30B cylinder except for its original point of contact, during both normal or accident conditions of transport.

The plug protecting device consists of a pot made of stainless steel (with its inner side painted with an intumescent material) welded to the inner shell of the bottom half of the PSP. The rotation preventing system consists of two rotation preventing devices installed at the sides of the inner flange of the bottom half of the PSP. The device consists of a stainless-steel pin accommodated in two sleeves, an internal sleeve in contact with the pin and an external sleeve which is welded to the flange. A handlebar is welded onto the steel pin to allow turning and lateral movements.

All the surfaces of the inner shell of the bottom half are covered with a layer of 2.6 mm intumescent material.

The nominal values of the PSP are the following: 1216 mm (nominal diameter), 1329 mm (nominal height), 2437 mm (nominal length), and a nominal gross weight of 4012 kg.

Generally, the DN30 package is transported on dedicated flat-racks. A maximum of four DN30 packages can be mounted onto a 20' flat-rack by bolting them down.

1.2 Contents

The content of the package is unirradiated commercial grade uranium, in the form of UF_6, with natural isotopic composition, and a U-235 mass percentage not to exceed 5 weight percent. The maximum quantity of material per package is 2,277 kg UF_6 contained in an ANSI Standard N14.1 30B cylinder.

1.3 Materials

The materials of the DN30 PSP are specified in the application, including the material properties of the PIR foam used as both shock absorbing and thermal insulating material along with the summary report of the tests performed on these materials as well as their results. The material properties of Promaseal® and MICROTHERM® OVERSTITCHED 1000R HY are also listed.

1.4 Drawings

The Model No. DN30 packaging is fabricated in accordance with

Drawing No. 0023-ZFZ-1000-000, Rev. 2 – DN30 PSP
Drawing No. 0023-ZFZ-1000-100, Rev. 0 – Closure Device
Drawing No. 0023-ZFZ-1100-000, Rev. 3 – Bottom Half
Drawing No. 0023-ZFZ-1200-000, Rev. 3 – Top Half
Drawing No. 0023-ZFZ-1120-400, Rev. 0 – Rotation Preventing Device
Drawing No. 0023-ZFZ-1140-000, Rev. 2 – Valve Protecting Device

1.5 Evaluation Findings

A general description of the Model No. DN30 package is presented in Section 1 of the package application, with special attention to design and operating characteristics and principal safety considerations. Drawings for structures, systems, and components important to safety are included in the application.

The application identifies the DNT Quality Assurance Program and the applicable codes and standards for the design, fabrication, assembly, testing, operation, and maintenance of the package.

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. DN30 package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL AND MATERIALS EVALUATION

2.1 Description of Structural Design

2.1.1 General

The DN30 is a Type AF package that is comprised of an outer stainless steel cylindrical body (PSP) housing the 30B cylinder (containment boundary) which carries UF_6.

The PSP has a clam shell design that utilizes a mortise-and-tenon closure system located on the exterior portion of the PSP. The PSP portion of the package has a stainless steel support structure (“feet”) which is used to tie down the package to a conveyance via bolts during transportation. Alternatively, straps can be used to tie down the package, if supporting calculations are provided and approved by the NRC.

The PSP portion of the package has both an outer and inner shell which is separated by an impact absorbing foam and fire-retardant material.

The applicant provided licensing drawings with tolerances, dimensions, welding symbols and definitions, material designation, and associated standards. Component description and arrangement of components relative to each other has been described and detailed by the applicant. The applicant describes the weight of the package with and without its contents as well as the overall physical dimensions of the package. The package dimensions are presented in Tables 11 and 12 of chapter 1. The maximum normal operating pressure of the package is dictated by the 30B cylinder design. Several attachments (lifting lugs) are located on the PSP to facilitate handing.

The staff has reviewed the package structural design description and concludes that the contents of the application satisfies the requirements of 10 CFR 71.31(a)(1)(c), 71.31(a)(2), 71.33(a), and 71.33(b).

2.1.2 Identification of Codes and Standards for Package Design

The material standards used for the package comply with ASTM standards (or ASTM equivalents) for the 30B cylinder.

The outer portion of the package, the PSP, utilizes European standards with applicable ASTM equivalents.

For simulation analyses, the applicant used LS-DYNA R8.0 (2015), and used ANSYS 19.0 to perform structural analyses. FKM (2012) was used to analyze bolt stresses and perform fatigue analysis of the package.

The applicant designed the package to meet 10 CFR Part 71 regulations, while the 30B cylinder is designed and manufactured in accordance with ANSI N14.1(2012).

2.1.3 Material Behavior Beyond Yield

The package's containment boundary does undergo inelastic deformation when subjected to drop testing for both normal conditions of transport (NCT) and hypothetical accident conditions (HAC). The applicant describes and characterizes the criteria used for inelastic strain in Section 2.1.2.1 of the application.

With respect to the containment boundary, the applicant does not approach the uniform elongation limit of the material when characterizing post yield behavior, which the staff finds acceptable since the inelastic behavior beyond yield is relatively small in the 30B cylinder. Staff noted that additional material testing would be needed to determine the uniform elongation limit to rupture behavior of the material, which the applicant has not submitted.

The staff has reviewed the structural codes and standards used in package design in addition to post yield material behavior and finds that they are acceptable, satisfying the requirements of 10 CFR 71.31(c).

2.1.4 Minimum Package Size

Given that the minimum package dimension is greater than 10 cm, the staff finds that the package satisfies the requirements of 10 CFR 71.43(a) for minimum size.

2.1.5 Tamper-Indicating Feature

The closure of the package is facilitated by a mortise and tenon system comprised of two steel blocks attached to both the top and bottom halves of the PSP at 6 locations. The mortise and tenon system is locked in place by a bolt, which secures both the top and bottom steel blocks. A pin then secures the bolt.

The pin and closure bolt are readily visible, and if missing, would tell the user that the closure device has been tampered with. As a result, the staff reviewed the package closure description and finds that the package satisfies the requirements of 10 CFR 71.43(b) for a tamper-indicating feature.

2.1.6 Positive Closure

Positive closure of the package is facilitated by a mortise and tenon system comprised of two steel blocks attached to both the top and bottom halves of the PSP at 6 locations which secure the both halves of PSP. The mortise and tenon system is locked in place by a key at 6 locations.

The pin in each of the 6 mortise and tenon devices is secured by screws which are torqued to 80 Nm including Nordlock washers, providing positive closure.

The staff reviewed the package closure description and finds that the package satisfies the requirements of 10 CFR 71.43(c) for positive closure.

2.1.7 Package Valve

The only portion of the package that has a valve is the 30B cylinder which is nested within the PSP when in use and is not accessible to unauthorized operation. The staff reviewed the package description and finds that the valve, the failure of which would allow radioactive contents to escape, is protected against unauthorized operation.

The staff reviewed the package closure description of the package and finds that it satisfies 10 CFR 71.43(e).

2.2 Lifting and Tie-Down Standards

2.2.1 Lifting Devices

The applicant describes lifting and handling of the package in Section 1.4.2.4 of the application and in Appendix 1.7.1. Calculations are proved in Section 2.2.1.2.3.

The package may be lifted in three different manners that could directly affect the 30B cylinder: (1) lifting the package (PSP and 30B cylinder) via 4 lugs connected at the feet of the PSP, (2) by fork lift utilizing 2 specially made fork lift pockets located under the PSP body to carry both the PSP and 30B cylinder, or (3) lifting of the top lid portion of the PSP using two lifting lugs. Lifting lugs are rendered inoperable by a bolt and nut when not in use.

Of all 3 lifting methods, method (1) is the most limiting where a safety factor of 4.4 is calculated using nominal shear stress rather than maximum shear stress for the case where all four lifting lugs are utilized (intended lifting manner). Details are provided in Table 24 of the application. In this lifting mode, friction forces which aid in lifting are neglected.

Based on the applicant’s calculations, the staff concluded that a safety margin greater than 3 exists with respect to yielding. Failure at this connection is based on bolt tear through of the lifting lugs that are welded to the feet which would not affect the rest of the package's ability to meet other lifting operations if they were to fail.

The staff has reviewed the lifting for the package and concludes that they satisfy the standards of 10 CFR 71.45(a) for lifting.

2.2.2 Tie-Down Devices

The package is tied down via the feet of the package which are bolted to a dedicated flat rack. The applicant provided calculations showing that the package may carry 5 times the weight of the package in the lateral direction, 10 times the weight of the package in the axial direction, and 2 times the weight of the package in the vertical direction.

Bolts at the tie-down location are not considered to be part of the package, and failure of the tie-down system (bolts) will not impair the ability of the package to meet other 10 CFR 71 requirements.

The staff has reviewed the tie-down requirements for the package and concludes that they satisfy the standards of 10 CFR 71.45(b) for tie-down.

2.3 General Considerations for Structural Evaluation of Packaging

The applicant evaluated the package with a combination of analytical tools and physical drop testing to determine the structural integrity of the package after being subjected to both NCT and HAC conditions. The applicant first did a pre-analysis using FEM tools to simulate drop testing, followed by physical testing of prototypes, followed by a refinement of the pre-analyses models to evaluate the package for additional analyses.

Specifically, the pre-analysis examined a sequence of drops with various package orientations as described in Section 2.1.3.1.2.1 but was not included in the application. Physical drop testing was performed at BAM's drop testing facility and consisted of 5 drop test sequences described in Section 2.3.1.2.2.

With respect to the drop tests cited for NCT and HAC, the applicant focused on assuring that the port and valve of the 30B cylinder were free from inelastic deformation as any damage to these components could cause unintended release of UF_6.

The staff reviewed the application and finds that the package was evaluated by subjecting a specimen in a manner acceptable to the Commission, and therefore satisfies the requirements of 10 CFR 71.41(a).

2.3.1 LS-DYNA model

The LS-DYNA model is comprised of about 250,000 elements with additional element geometry considerations tabulated in Table 33 of the application.

The models used to simulate drop test conditions is composed primarily of shells (default based Belytschko, Lin and Tsay ELFORM 2) with hour glass control, and default solid eight-node hexahedron elements (ELFORM 1). Beam elements (ELFORM 1) are used to model the sleeve to pin connection. The applicant provided this information in Table 4-4 of the structural analysis appendix. The *CONTACT_AUTOMATIC_SINGLE_SURFACE option was used to simulate contact between parts with a friction value of 0.15 (dry steel to steel) and viscous damping of 20%.

Material properties have been provided through catalog cuts, physical testing, and tabulated values in relevant codes and standards. Specifically, the applicant developed foam characteristics from physical testing and LS-DYNA simulation.

Steel was modeled using **MAT_MODIFIED_PIECEWISE_LINEAR_PLASTICITY* while both types of foam (RT 160 and RT 320) were modelled as **MAT_CRUSHABLE_FOAM.* Table 32 under Section 2.2.1.5.1.3 of the application also describes simplifications made in developing the model. Drop sequences were initiated with start/stop options in LS-DYNA. The staff agrees that the model simplifications made by the applicant will not impact the performance of the package.

2.3.2 Contents Modeling

UF_6 in solid form was characterized by the applicant as having a crystalline structure in solid state. The applicant simulated the contents as being one large block of material, rather than a collection of fractured pieces that may exist within the 30B cylinder and noted that a single block carries more kinetic energy than several smaller pieces. The solid piece approach matches the physical drop testing performed using concrete and steel as a surrogate.

The applicant has assumed that the 30B cylinder is lying on its side, and that the UF_6 fills 60% of the available volume in the cylinder. Fractures or fissures of the material have been described by the applicant as appearing in the plane occupying the radius of the 30B body. Given this geometry, the contents, even if fractured, are immediately restrained geometrically from detaching from the 30B and striking the other side of the cylinder during drop simulations.

The applicant also considered the scenario where the 30B cylinder is filled to less than 50% of the volume within the 30B cylinder.

2.3.3 Hour Glassing

The applicant conducted sensitivity studies of observed hour-glassing in certain portions of the package. Additional studies were performed for certain parts that had large hour glassing aspects. These additional investigations are captured in Technical Note 0023-BBR-2019-004 (Appendix 1).

By examining deformations in the hour-glass sensitivity analysis, the applicant demonstrated how excessive amounts of hour glassing in certain portions of the package will not significantly affect the performance of the 30B cylinder within the DN30. Staff agrees with the approach and results of the sensitivity study.

2.3.4 Tied Contacts

The applicant used tied contacts to simulate welds within the 30B cylinder. These welds often had regions of inelastic deformation during NCT and HAC drops. The applicant justified their use by performing a sensitivity study that used additional shell or solid elements to model the welds and showed that package behavior remains accurate when using tied contacts. This sensitivity analysis was captured in Chapter 4 of Technical Note 0023-BBR-2019-004 (Appendix 1).

Specifically, a refined modeling in this technical note demonstrated that plastic strains in the tied contact region are actually smaller than initially reported when additional shell and solid elements are used, which means that tied contacts lead to more conservative results.

2.3.5 Post Yield Material Modeling

The applicant provided stress strain curves for post yield behavior of the steel used to characterize the 30B cylinder.

These curves however did not fully capture the behavior of the material in the region of the uniform elongation limit and beyond to rupture, since actual material testing was not used. The applicant instead derived mathematical arguments in this range.

However, accurate material behavior beyond the uniform elongation limit is not necessary in this case as the 30B cylinder only observes small inelastic strains which are well below the uniform elongation limit.

The staff agrees with this approach as there is ample residual capacity in the material and thus built in conservatism with respect to the packages structural integrity.

2.3.6 ANSYS model

The applicant did not explicitly model the closure device (6 in total) in LS-DYNA. Instead, a cruder representation of the closure device was used which consisted of two blocks. Force and displacement output from LS-DYNA at these regions and was used to perform a quasi-static analysis with ANSYS. The ANSYS FEM model used primarily tetrahedral elements to explicitly modeled the closure device.

The applicant performed mesh sensitivities to determine an acceptable mesh size. The pin and remaining portion of the closure device were analyzed with both force and displacement inputs to determine if the closure devices fails in tension. In this case the pin would have to be sheared in this failure mode as both upper and lower parts of the PSP would have separated for this to occur.

The applicant determined that the closure device will not fail under NCT and HAC conditions.

2.3.7 Benchmarking and validation

The applicant benchmarked and validated FEM efforts (LS-DYNA and ANSYS) in Appendix 2.2.1.1 (Drop Test Program), Appendix 2.2.1.2 (Drop Test Reports), and Appendix 2.2.1.3 (Structural Analysis of the DN30 Package under NCT and ACT).

The applicant first performed preliminary calculations using FEM tools and compared those results to prototype drop testing. The applicant then adjusted the models using drop testing data and then investigated the package for other drop scenarios. The applicant used a sequence of drop tests based on the 1.2 m (NCT), 9 m (HAC), and 1 m puncture (HAC) tests in an attempt to cause maximum damage to the port, valve, the remaining part of the 30B cylinder, and closure system.

The applicant used predicted deformations, decelerations, and contents movement obtained from FEM simulations to validate the package. Physical testing used in the validation was based on five drop test sequences performed at the German Federal Institute of Materials Research and Testing (BAM) facility. Physical measurements were made to determine if the predicted deformations came within 10% of the actual measurements.

The applicant compared measured accelerations from drop testing to simulated decelerations produced from LS-DYNA. The applicant conducted mesh and material sensitivity studies (foam) to determine the influence of varying foam mechanical properties.

Refinement of the mesh was halted when the applicant found only a difference of 2 or 3% in results between the two. Foam property variations were only found to result in deformation estimates that were often less than 0.5%.

2.3.8 Drop testing campaign

The applicant had an initial drop testing program campaign during 2011-2012 which used a total of 6 specimens. The applicant modified the package and FEM models, as a result of those tests. In 2013-2014, the applicant performed additional drop testing for 3 more sequences utilizing 3 full size prototype test specimens. Four 30B cylinders were used as test specimens.

The applicant performed 7 separate drops for NCT with an additional 16 drops for HAC. A total of 6 sequences using a combination of NCT and HAC drops were performed.

Drop tests, performed at BAM, are documented in Appendix 2.2.1.1. Additional details such as specimen construction, drop orientation, video recording, sampling speed, test preparation, etc. are described by the applicant in the appendix as well as BAM drop tests reports (Appendix 2.2.1.2). The target used for drop testing consisted of 14 m x 14 m x 5 m concrete block faced with a 220 mm thick steel plate. The target has a total mass of 2,600,000 kg and the DN30 is not expected to exceed 4,400 kg when fully loaded. Staff agrees that the target meets the requirements of an unyielding target.

2.4 Normal Conditions of Transport

The acceptance criteria used by the applicant for NCT was to demonstrate that the valve and port and the 30B cylinder in general is not breached during NCT.

2.4.1 Heat

The applicant stated package temperatures corresponding to an ambient temperature of 38°C with solar insolation, matching the 38°C ambient temperature dictated by Part 71. Thus, staff concludes that the heat requirements for the package satisfy the standards of 10 CFR 71.71(c)(1).

2.4.2 Differential Thermal Expansion

The applicant considered differential thermal expansion of the package as mentioned in Section 2.2.1.2.4 of the application. The applicant considered scenarios where the surface of the PSP is 100°C or 20°C, while the 30B cylinder alternates between 20°C and 64°C and found that the package has enough space between components to avoid thermally induced stresses via contact.

The applicant states that, according to ANSI N14.1, the 30B cylinder is designed for a temperature range of -40°C to 121°C which covers the temperature range of the package (-40°C to +70°C). An additional analysis was conducted by the applicant in Section 2.2.1.6 to demonstrate that thermal stresses caused by the shrinking or expanding of gaps between metallic components and the foam will not affect the package ability to meet 10 CFR Part 71 when temperatures are at (-40°C, and 60°C).

2.4.3 Cold

The applicant used a minimum temperature of -40°C to perform drop testing and used material properties at this temperature.

The staff has reviewed cold requirements for the package and concludes that they satisfy the standards of 10 CFR 71.71(c)(2).

2.4.4 Reduced External Pressure

The 30B cylinder is designed to ANSI N14.1 for an external pressure of 172 kPa (25 psi) and an internal pressure of 1.38 MPa (200 psi). It carries a pressure of 152 kPa (22 psi).

Since the 30B cylinder is capable of withstanding an additional 188.8 psi relative to 3.5 psia (200 psi – (14.7 psi (1 atm) – 3.5 psi)), the staff concludes that the package satisfies the standards of 10 CFR 71.71(c)(3) for reduced external pressure.

2.4.5 Increased External Pressure

The 30B cylinder is designed for an external pressure of 172kPa (25 psi) and an internal pressure of 1.38 MPa (200 psi). It carries a pressure of 152 kPa (22 psi). Since the 30B cylinder is designed for 25 psi vs 20 psia, the staff concludes that the package satisfies the standards of 10 CFR 71.71(c)(4).

2.4.6 Vibration and Fatigue

The applicant evaluated fatigue at the lifting points and connections of the package for three different lifting operations and assumed the package will see only 100 cycles per shipment, 12 times a year, for 30 years. Stresses were obtained via classic hand calculations and FEM via ANSYS.

The applicant used stresses that are permitted for 100,000 cycles according to FKM 2012 to evaluate fatigue. This is conservative given that the package is not expected to undergo 100,000 cycles and corresponds to stresses that are higher than calculated.

The applicant determined that the stress amplitude for this design is less than 50% of the available capacity for the material. The applicant also utilized an amplification factor of 1.3 when calculating alternating stresses. The staff found the fatigue evaluation performed by the applicant to be acceptable.

The staff has reviewed vibration and fatigue requirements for the package and concludes that they satisfy the standards of 10 CFR 71.71(c)(5).

2.4.7 Water Spray

The applicant stated that the outer shell of the DN30 (PSP) has no openings, has a gasket, and is shaped to prevent water ingress. As a result, the staff agrees that the water spray test will not impair the package and concludes that they satisfy the standards of 10 CFR 71. 71 (c)(6).

2.4.8 Free Drop

The applicant examined the package for a 1.2 m free drop at various orientations and at temperatures that varied from -40°C and +60°C. Only very small isolated spots of inelastic deformations were found on the 30B cylinder (neglecting the skirts) during drop sequences:

Sequence 1-2 resulted in an inelastic strain of 1.7×10^{-2}
Sequence 3-2 resulted in an inelastic strain of 5.589×10^{-3}
Sequence 8 resulted in an inelastic strain of 2.951×10^{-2}
Sequence 10 resulted in an inelastic strain of 2.190×10^{-2}

that are based on more bounding HAC drop tests.

These small deformations are less than the threshold values cited by ANSI N14.1 that would warrant concern and/or repair. Specifically, USEC UF_6 Manual, and ANSI N14.1 all provide examples of acceptable damage to UF_6 cylinders. The port and valve remained free of damage.

With respect to the closure device, inelastic plastic deformation of the pin did not exceed 6% in any of the simulations, well below the 35% rupture strain value for the pin's material. None of the simulated free drops or drop tests resulted in the failing of the PSP's closure device.

As a result, the staff has reviewed the package for Free Drop and concludes that the regulatory requirements of 10 CFR 71.71(c)(7) are satisfied.

2.4.9 Corner Drop

Not applicable since the package exceeds the minimum weight. As a result, 10 CFR 71. 71(c)(8) is not applicable.

2.4.10 Compression

With regards to compression, the applicant performed a quasi-static FEM analysis for compression (Section 2.2.1.4.3). The results show that only very local and very small plastic deformation (dents) below 5 % elongation occur at the outer shell that have no impact on any safety feature of the DN30 PSP.

As a result, staff agrees with the applicant that the package satisfies the requirements of 10 CFR 71.71(c)(9).

2.4.11 Penetration

The outer portion of the PSP package is made of stainless steel and does not have any valves or opening that would be susceptible to 6-kg bar impacting it. The applicant states the PSP is designed to withstand the puncture test which is more severe than the penetration test.

The staff agrees that the DN30 package is not susceptible to the 6-kg bar and concludes that they satisfy the regulatory requirements of 10 CFR 71.71(c)(10).

Conclusion

The staff reviewed the structural performance of the packaging under NCT and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the regulatory requirements for a Type AF package.

2.5 Hypothetical Accident Conditions

Similarly to NCT conditions, the acceptance criteria used by the applicant was to demonstrate that the valve and port are undamaged and that the 30B cylinder (containment boundary) is not breached during HAC.

The applicant describes the DN30 package's ability to withstand HAC conditions in appendices 2.2.1.1 (Drop test Program), 2.2.1.1 (Drop test reports), 2.2.1.2, and 2.2.1.3. The drop tests considered the 1.2 m free drop, the 9 m drop, and the 1m puncture test for cumulative damage with relevant package orientations as described in Section 2.2.1.5.1.1 of the application. The applicant also considered temperatures ranging from -40°C and +60°C. In general, the applicant described the higher g loads will be experienced by the package at -40°C since the material of the package is stiffer along with expected smaller deformations, while the opposite is true at +60°C.

The staff agrees that the applicant used the most damaging ordinations to challenge the package.

2.5.1 Free Drop

In Section 2.2.1.5.1.1 of the application, the applicant explored sequences and orientations that were expected to cause maximum damage to the containment boundary. The applicant not only examined individual 9 m free drops but also considered cumulative damage based on a sequence of drops as described in Section 2.2.1.5.1.1.

Staff agrees that no damage was noted near the port or valve of the 30B cylinder after the drop sequences conducted by the applicant. The applicant considered the maximum deformation that could lead to damage at critical areas and temperatures ranging from -40°C and +60°C.

Inelastic deformation to the 30B cylinder is determined from LS-DYNA. Only very small isolated spots of inelastic deformations were found on the 30B cylinder (neglecting the skirts) after HAC sequences. Specifically:

Sequence 1-2 resulted in an inelastic strain of 1.7×10^{-2}

Sequence 3-2 resulted in an inelastic strain of 5.589×10^{-3}
Sequence 8 resulted in an inelastic strain of 2.951×10^{-2}
Sequence 10 resulted in an inelastic strain of 2.190×10^{-2}

These deformations are less than the threshold values cited by ANSI N14.1 that would warrant concern and/or repair. Specifically, USEC UF_6 Manual, and ANSI N14.1 provide examples of acceptable damage to UF_6 cylinders. Additional details were provided by the applicant in chapter 6 of Technical Note 0023-BBR-2019-004 (Appendix 1) demonstrating that acceptable "dents" to the 30B were below those observed during drop testing and simulation.

With respect to the closure device, inelastic plastic deformation of the pin did not exceed 6% which is well below the pin's 35% rupture value. As a result, the closure device does not fail. Based on the applicant modeling and testing, the staff agrees that the DN30 package meets the requirements for Free Drop and concludes that the requirements of 10 CFR 71.73(c)(1) are satisfied.

2.5.2 Crush

Not applicable as the package weighs more than 500 kg.

2.5.3 Puncture

The applicant considered the most damaging orientation for key components of the 30B cylinder such as the port. The applicant examined the orientation where the center of gravity passes through the puncture bar itself. LS-DYNA simulations of drop sequences (cumulative damage) that included the puncture bar indicated that there was no damage to key 30B components.

Specifically, when puncture follows free drop in a damage sequence, the applicant demonstrated that the valve and port remained intact and undamaged. The applicant provided additional details in Chapter 6 of Technical Note 0023-BBR-2019-004 (Appendix 1) demonstrating that the observed damage to the 30B cylinder ("dents") does not exceed acceptable damage limits according to ANSI N14.1.

As a result, the staff has reviewed the package for puncture and concludes that the requirements of 10 CFR 71.73(c)(3) are satisfied.

2.5.4 Thermal

The applicant described the condition of the 30B cylinder prior to the fire test with pre-existing inelastic deformations observed during sequence drops. The applicant In Section 2.2.2.3.5.2 of the application describes how the 30B cylinder will continue to have pressure values below the design pressure during the fire test. As a result, the staff has reviewed the package for thermal effects and concludes that the package is in compliance with 10 CFR 71.73(c)(4).

2.5.5 Immersion - Fissile Material

The 30B cylinder is designed for an internal pressure that exceeds that expected at 0.9 m. As a result, the staff has reviewed the package for Free Drop and concludes that the package is in compliance with 10 CFR 71.73(c)(5).

2.5.6 Immersion - All Packages

The 30B cylinder is designed for an internal pressure that exceeds that expected at 50 ft of water. As a result, the staff has reviewed the package for immersion and concludes that it is in compliance with 10 CFR 71. 73(c)(6).

2.5.7 Immersion - Air Transport Accident Conditions for Fissile Material

Air transport of the package is not permitted and, as a result, the requirements of 10 CFR 71.55(f) do not apply.

2.5.8 Immersion - Special Requirement for Type B Packages Containing More Than 10^5 A_2

Since the DN30 is a type AF package, the requirements of 10 CFR 71.61 do not apply.

2.5.9 Conclusion

Based on hand calculations, drop testing, validation and benchmarking efforts, and FEM simulation results presented by the applicant, the staff concludes that the DN30 packaging complies with 10 CFR 71.73.

2.6 Materials Evaluation

The DN30 packaging is in compliance with 10 CFR 71 requirements when containing commercial grade uranium with less than 1 A_2 quantity and an enrichment of no more than 5 wt.% U-235.

The DN30 packaging consists of the DN30 Protective Structural Packaging (PSP) and the 30B cylinder specified in ANSI N14.1. The 30B cylinder uses: (i) carbon steels meeting heat treatment and supplementary requirements, (ii) aluminum bronze and nickel copper alloy, (iii) tin-leader solder, conforming to ASTM requirements, (iv) packing and port cap gasket made from 100% virgin unfilled Teflon at below the Teflon's allowable service temperature limit, and (v) a valve-buyer approved fluorinated lubricant.

The DN30 PSP materials are stainless steels conforming to ASTM/ASME requirements. Requirements for welders and welding are defined to ensure the structural properties of the DN30 PSP. The staff determines the use of the standards of ASTM, ASME and ANSI to be acceptable and have been approved in other transportation cases.

The design of the DN30 PSP complies with drawings, specifications, testing and documentation during manufacturing. The drawings comply with NUREG/CR-5502. The gasket is made of EPDM. Foam is a rigid Polyisocyanurate (PIR form). Thermal insulation (intumescent material) is made of Promaseal-PL or MICROTHERM, and thermal plugs are made of Polyamide. The detailed properties of the insulation are presented separately in thermal test reports and analyses in the application's appendices.

The DN30 package is under an ambient temperature of 38˚C. The HAC ambient temperature is 800˚C for 30 minutes. The lowest temperature without insulation is – 40˚C. Specific temperatures for various components are used based on the assumptions from thermal properties, and, therefore they are acceptable.

Although thermal and mechanical properties are presented extensively, many of the properties are assumptions or qualitative presentations. Some allowable materials service temperatures are given in Table 1 of the appendix of the thermal analysis. The applicant provided a basis and or justification for estimated (or assumed) values for material properties from drop tests, the HAC calculations, and open literature data. The staff determined that this was acceptable, based on its own review of the tests, calculations, and literature data.

The safety analysis does not discuss the effects of radiation on materials stability and gas (e.g., hydrogen) generation, except that dose limits are presented. Based on the applicant's dose strength, the staff independently assessed materials reactions with radiation by radiolysis and literature data and potential gas generation. The staff concludes that potential hydrogen gas generation, isolated in the pores of the foam, is not significant with respect to the safety limit of 5 %. The staff notes that the structural stability of the foam will be also maintained under the stated dose limits based on literature data. The staff finds that the 10 mSV/h on the surface is acceptable to comply with 10 CFR 71.47, meeting the conditions for exceeding 2 mSv/h.

The applicant specified the material properties and welding/fabrication procedures based on ASME BPVC Section II Part A, ASME BPVC Section VIII Division 1, ANSI N14.1, and ASTM standards.

The staff reviewed the applicability of these options and determined these options are acceptable. ASME Code, Section VIII, Division 1, includes rules for the construction of pressure vessels and considers all separate BPVC Sections III, V and IX. The staff also determined that other Codes and standards used are acceptable, following the staff previous approvals of other transportation applications.

The staff reviewed fracture properties and bolt performances, and determined that the applicant complies with the staff's determination for other approved transportation cases. The fracture analysis at -40 ˚C is not required by the ASME Code for components constructed of austenitic stainless steels. The absence of structural defects in bolts is confirmed.

The staff reviewed the Codes and Standards used by the applicant. The applicant provided the relationship between International Codes and Standards and 10 CFR 71. The staff determined that the relations are appropriate with respect to Codes and Standards used in U.S.

Regarding a potential formation of volatile HF, the staff finds that the degree of formation of HF is acceptable based on the staff's assessment of the HF formation and ANSI N14.1. The staff calculated the radiolysis kinetics based on literature information.

The applicant provided information on how to determine excessive corrosion of coating and the staff finds the determination acceptable based on the applicant's quantitative judgment based on available literature data. To the maximum credible extent, there are no significant chemical, galvanic or other reactions for each packaging component, among the packaging components, among package contents, or between the packaging components and the contents in dry or wet environment conditions. The effects of radiation on materials are evaluated. Regarding the potential embrittlement by radiation, the package containment is constructed from materials that meet the requirement of Regulatory Guides 7.11 and 7.12 for embrittlement.

3.0 THERMAL EVALUATION

The objective of this review is to verify that the thermal performance of the package design has been adequately evaluated for the thermal tests specified under NCT and HAC, and that the package design meets the thermal performance requirements of 10 CFR Part 71.

3.1 Description of Thermal Design

Section 1.4.1, "List of All Packaging Components and Complete Design Drawings," of the application describes that the DN30 packaging consists of the DN30 Protective Structural Packaging (PSP) and the 30B cylinder specified in the American National Standards Institute (ANSI) N14.1, "American National Standard, for Nuclear Materials – Uranium Hexafluoride – Packagings for Transport." The applicant described that the DN30 PSP provides thermal protection for the 30B cylinder and its radioactive contents.

Section 1.4.2.3.3, "Thermal Protection System," of the application describes that the thermal protection system consists of the stainless steel and insulating foam structure of the bottom and top half of the DN30 PSP, the insulating MICROTHERM® layer between the polyisocyanurate rigid foam (PIR) RTS 120 foam and the steel, and the intumescent material, which is material that expands when exposed to heat, Promaseal-PL® at the inner surfaces of the DN30 PSP.

Sections 1.4.2.3.5, "Valve Protecting Device," and 1.4.2.3.6, "Plug Protecting Device," described that the inside of the valve protecting device and plug protecting device, respectively, is covered with intumescent material. Based on the staff's review of the description of the thermal design, the staff finds the description of the thermal design acceptable.

3.1.1 Design Features

Section 1.4.6, "The Components of the Packaging Relevant for Thermal Protection," of the application describes that the DN30 PSP inner and outer shells, PIR RTS 120 and 320 foam, MICROTHERM® layer between the inner shell and RTS 120 foam, and intumescent material Promaseal-PL® attached to the inside of the inner shell provide thermal protection.

Section 1.4.1.2, "DN30 PSP," of the application also described that the PIR foam is used as thermal insulating material. Based on the staff's review of the design features, the staff finds the design features to be acceptable.

3.1.2 Contents Decay Heat

The total heat generation, 0.172 Watts (W), for 2277 kilograms (kg) of UF_6 with the composition from Table 1, "Content of enriched commercial grade UF_6 complying with ASTM C996," of the application is provided in Table 3, "Heat generation rate of 2277 kg UF_6 with the composition given in Table 1," of the application. Section 1.3.5, "Limitation of the Heat Generation Rate of the Content," of the application describes that a conservative heat generation of 3 W is used in the thermal analysis. The staff finds the use of a 3 W decay heat in comparison to the total heat generation of 0.172 W to be conservative and 10 CFR 71.33(b)(7) is met.

3.1.3 Summary Tables of Temperatures

The applicant provided the maximum allowable temperature limits for the components of the DN30 and 30B cylinder for NCT and HAC in Table 52, "Admissible component temperatures of the package DN30," of the application. Section 2.2.2.1.4, "Admissible component temperatures of the DN30 package," of the application that the 30B valve and cylinder maximum allowable temperature during HAC was based on a temperature that would impact the structural integrity of the package; therefore, the applicant chose the maximum temperature limit, 131°C (268°F), that still retains a safety margin of 1.05 to the valve test pressure 2.76 megapascal (MPa) (400 pounds per square inch gauge (psig)) described in ANSI N14.1 for the 50% and 100% filling ratios.

Also, in Section 2.2.2.1.4 of the application, the applicant described a stress analysis at the maximum allowable temperature for the 30B cylinder during HAC that considered the possible pressure build-up due to elevated temperatures and the melted UF_6 contents, where the results showed the calculated stresses were below the allowable stresses. The staff finds this justification for the maximum allowable temperature of the 30B cylinder and valve to be acceptable.

The applicant provided the maximum component temperatures in Table 64, “Temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder under RCT and NCT,” of the application for NCT and Table 65, “Maximum temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder,” of the application for HAC.

The staff finds the applicant showed the maximum component temperatures in Tables 64 and 65 of the application are below the maximum allowable temperature limits in Table 48 of the application, and therefore are acceptable.

3.1.4 Summary Tables of Maximum Pressures in the Containment System

Section 1.2.8, “Maximum normal operating pressure,” of the application describes the maximum normal operating pressure for the DN30 package is defined as the pressure at the triple point of UF_6, which is equal to 152 kilopascal (kPa) (22.05 psig).

Section 2.2.2.1.4 of the application describes the maximum internal pressure in the 30B cylinder is 2.57 MPa (373 psig) during HAC which is less than the valve test pressure 2.76 MPa (400 psig) described in ANSI N14.1, and therefore the staff finds is acceptable.

The applicant clarified in Section 1.4.2.3.1, “Pressure envelope of the DN30 package,” of the application that the DN30 PSP is not designed to be a pressure retaining component. The applicant also clarified in Section 1.4.2.3.1 of the application, for release of pressure during HAC, the DN30 PSP is equipped with fusible plugs which will release any pressure induced by the decomposition of the foam.

3.2 Material Properties and Component Specification

The applicant described the DN30 PSP material specifications in Table 6, “Material Specification of the DN30 PSP,” and of the PIR foam in Table 7, “Properties of RTS 120 and RTS 320 (according to the technical data sheets),” of the application. The material properties are evaluated in Chapter 2 of this safety evaluation report (SER).

The applicant described that the thermal tests with samples of the PIR foam used in the DN30 PSP are documented in Section 4, “Thermal Properties,” of Appendix 1.4.2, “Material Data PIR Foam.” The applicant summarized in Section 1.4.1.2.2, “Thermal tests with samples of RTS 120 and RTS 320,” that the thermal properties of the foam were determined up to approximately 250°C (482°F), beyond which the foam disintegrates; however, no dangerous gases are produced; in addition, the applicant described that the results of the tests were used in the thermal analysis.

Based on the staff's review of the conclusion and summary of the released gases in Appendix 1.4.2, the staff confirmed that no dangerous gases are produced.

The applicant described that the thermal tests with samples of the intumescent material used in the DN30 PSP are documented in Appendix 1.4.3, "Material Data Intumescent Material," including tests that measured heat capacity, thermal expansion, thermal conductivity, and force of expansion; the applicant also described that the results of the tests were used in the thermal analysis.

Based on the staff's review of Appendix 1.4.3, the staff accepts the applicant's conclusion that neither the 30B cylinder valve nor the plug will be damaged by the expansion of the intumescent material.

3.2.1 Material Properties

The applicant described in Section 2.1.1.1, "Content," of the application for the thermal analysis the important physical properties are the density, the thermal conductivity and the specific heat capacity. The applicant continued to describe that it is assumed that the UF_6 fills approximately 60% of the lower part of the cylinder, and that partial filling scenarios are analyzed too, from 2277 kg UF_6 to an empty cylinder containing heels.

The applicant described in Section 2.1.1.2, "30B Cylinder," of the application that standard material properties are assumed for the 30B cylinder. The applicant described in Section 2.1.1.3, "DN30 PSP," of the application that for NCT standard material properties are assumed for the DN30 PSP, and for HAC deteriorated material properties are assumed for the DN30 PSP.

In Table 15, "Thermal Properties of Used for the Analysis," of the application the applicant provided the thermal conductivity, density, and heat capacity at 20°C (68°F), with complete thermal properties provided in Appendix 2.2.2.3, "Thermal Analysis," of the application. The material properties are evaluated in Chapter 2 of this SER.

3.2.2 Component Specification

The applicant described in Section 2.1.2.2, "Thermal Design," of the application that the temperatures at the thread connections between the 30B cylinder valve and cylinder, and the 30B cylinder plug and cylinder should not exceed 131°C (268°F) during the thermal fire test simulating HAC.

The applicant specified in Section 1.2.7, "Lowest Transport Temperature for which the Package is Designed," of the application that the components were good to -40°C (-40°F). The staff requested justification that the DN30 PSP components are not degraded at -40°C (-40°F) in the request for additional information (RAI) 3.11 (Agencywide Document Accession Management System (ADAMS) No. ML19170A223), the applicant specified in the response to RAI 3-11 that the PIR foam does not degrade, the MICROTHERM® is suitable, and the Promaseal-PL® does not deteriorate at -40°C (-40°F). Therefore, the staff finds that the components are good to -40°C (-40°F).

The applicant also specified in Section 2.1.2.2 of the application that the leakage rate after the thermal fire test should be less than 1×10^{-4} pascal cubic meter per second (Pa-m^3/s) (9.87×10^{-3} reference cubic centimeter per second (ref-cm^3/s)) and there should be no failure of the 30B containment system. The staff finds that these component specifications meet 10 CFR 71.71(c)(2), and because it is a Type A package the leakage rate meets 71.51(a)(1) and (2).

3.3 General Considerations

The applicant described in Section 2.1.3.2.2.1, “Pre-analysis,” of the application that the following conservatisms were considered: the condition of the DN30 PSP after an accumulation of a full drop test sequence on the valve side and the plug side, and an empty 30B cylinder to minimize the thermal heat capacity and therefore maximize the temperature of the cylinder.

Based on the staff’s review of the drop test sequence, the staff finds that these assumptions will maximize the temperature of the cylinder.

3.3.1 Evaluation by Analysis

The applicant described in Section 2.2.2.3.1, “Software,” that the thermal analysis was performed using the computer software ANSYS Workbench version 19.0 and two fire tests with DN30 prototypes were used to validate the thermal analysis models. The applicant also described that the thermal conductivity of the PIR foam, and the fact that the PIR foam acts as a power source as it burns and cools, were both adjusted in the thermal analysis models to match the maximum temperatures in the thermal fire test. Section 2.2.2.3.2.2.2, “Heat generation due to incineration of the foam,” of the application describes the heat generation from the incineration of the foam parts and the associated benchmark analysis results to arrive at the best fit to the measured temperatures from the thermal fire test.

Section 2.2.2.3.2, “Calculation model,” of the application describes that an axisymmetric two-dimensional model where the axis of symmetry runs longitudinally through the center of the cavity, and the dimensions of the 30B cylinder and the DN30 PSP were also described. Figure 122, “Geometry of the calculation model for the DN30 package, full view,” shows the two-dimensional thermal analysis model and the materials of each component.

Based on the staff’s review of the description of the model in Section 2.2.2.3.2 of the application, Figure 122 of the application, in addition to the staff’s review of the thermal model description and analysis in Appendix 2.2.2.3, “Thermal Analysis of the DN30 Package for the Transport of Uranium Hexafluoride,” the staff finds the thermal requirements of 10 CFR 71.33(b)(5)(v) and 71.35(a) are met.

3.3.2 Evaluation by Test

The applicant described in Section 2.1.3.2.2.3, “Refinement of the calculation model and analysis for RCT, NCT, and HAC,” of the application that the two fire tests conducted in September 2016 and November 2017 were used to refine and benchmark the thermal models. The applicant designated the prototype without the MICROTHERM® insulation layer tested in September 2016 as, “Benchmark 2,” and the prototype with the MICROTHERM® insulation layer tested in November 2017 as, “Benchmark 1.”

For the two fire tests that were performed with two DN30 packages containing an empty 30B cylinder, the DN30 was pre-damaged by a full drop test sequence on the valve side, followed by a full drop test sequence on the plug side. The applicant also described in Section 2.1.3.2.2.2, “Experimental fire tests,” of the application that the DN30 was also heated to approximately 63 °C (145 °F) to account for an ambient temperature of 38 °C (100 °F) and insolation. The thermal fire tests are documented in Appendix 2.2.2.2, “Thermal test report,” of the application. Based on the staff’s review of the two fire tests used to benchmark the applicant’s thermal analysis results, the staff found the fire tests met the test conditions in 10 CFR 71.73(b).

The applicant described in Section 2.2.2.2.1, “Preparation of the thermal test,” of the application that the thermal test was performed on prototypes that had been tested according to drop test sequence 7. The drop tests sequence included: a 10.2 meter (m) (a combination of the 1.2 m free drop and 9 m drop) corner drop onto the DN30 PSP valve side, a 1 m drop onto a bar onto the DN30 PSP valve side, a 10.2 m corner drop onto the DN30 PSP plug side, and a 1 m drop onto a bar onto the DN30 PSP plug side. Based on the staff’s review of the drop test sequence, the staff found this drop test sequence to meet 10 CFR 71.73.

The applicant described the differences between the prototypes and the design of the DN30 package in Section 2.2.2.2.1.2, “Differences between prototypes and series design of the DN30 Package,” of the application; as well as the location of the temperature sensors in Section 2.2.2.2.1.3, “Temperature sensors,” of the application. The applicant also described the deviations of the test conditions from the test conditions required by the International Atomic Energy Agency (IAEA) in section 2.2.2.2.1.4, “Test conditions of the thermal test compared to the test conditions required by [10 CFR 71] and [IAEA 2012],” as well as measures taken to compensate for any differences. The staff finds it to be acceptable that propane fuel is a hydrocarbon fuel which does not produce as much soot as kerosene fuel, therefore the applicant painted the DN30 prototype black to meet the required 10 CFR 71.73(c)(4) surface absorptivity of 0.8. The staff also finds it to be acceptable that the DN30 prototype was preheated to 63°C (145°F) to conservatively compensate for temperatures reached with insolation applied.

The applicant described in Section 2.2.2.2.2, “Performance of the thermal test,” of the application the DN30 PSP fully engulfing fire, and the DN30 PSP natural cool down where no artificial means of cooling were used. The applicant also described an average flame temperature of 934°C (1732°F) for the Benchmark 1 fire test, and that the thermal plugs behaved as expected, allowing foam decomposition gases to escape. Therefore, the staff concludes there will not be a pressure buildup within the package during HAC conditions.

The applicant provided the maximum temperatures of the 30B cylinder, plug, and valve after the fire for Benchmark 1 and 2 tests in Tables 55, “Maximal temperatures at the 30B cylinder in the thermal test (Benchmark 1),” and 56, “Maximal temperatures at the 30B cylinder in the thermal test (Benchmark 2),” respectively, of the application. Table 56 of the application shows that the maximum allowable temperature limits of the plug and valve were exceeded during the first fire test.

The applicant considered the results of the first fire test to make design modifications that were tested in the second fire test. The applicant described in Section 2.1.4.2.6, “Layer of MICROTHERM® between RTS 120 foam and inner shell,” of the application that results of the second fire test showed that the addition of the MICROTHERM® between the RTS 120 foam and inner shell reduced the temperature of the valve and plug to be below 131 °C (268 °F). The applicant also described in Section 2.1.4.2.7, “Intumescent material,” of the application that the addition of the intumescent material prevented hot gases from the decomposition of the PIR foam from entering the cavity of the DN30 PSP, therefore suppressing any heat transfer by convection between the DN30 PSP and the 30B cylinder.

The applicant also described in Section 2.1.4.2.8, “Housing of the valve protecting device,” of the application that the housing of the valve protection device was redesigned to prevent a temperature increase in the 30B cylinder. The applicant also described in Section 2.1.4.2.9, “Thermal plugs,” of the application that the design, position, and number of the thermal plugs were modified to prevent a temperature increase in the 30B cylinder. The results of the second fire test in Table 55 of the application show that the 30B cylinder, plug, and valve maximum temperatures remain below the maximum allowable temperature limits, and the staff finds the temperature results to be acceptable.

The applicant summarized in Section 2.2.2.2.3, “Results of the thermal test,” of the application that the intumescent material expanded as expected to seal gaps between the 30B cylinder and the inner shell of the DN30 PSP and enclosed the valve and the plug completely resulting in no deformation of the 30B cylinder, the valve, or the plug. The leakage rate after the Benchmark 1 thermal test is 6.63×10^{-9} Pa-m^3/s (6.54×10^{-8} ref-cm^3/s), and the staff finds that is less than the acceptance criterion 1.0×10^{-4} Pa-m^3/s (9.87×10^{-4} ref-cm^3/s) that the applicant described in Section 2.1.3.3, “Containment design analysis,” of the application. Based on the staff’s review of the description of the package redesign and the results of the second fire test, the staff finds that the 30B cylinder, plug, and valve will remain below the maximum allowable temperature limits to maintain containment.

3.4 Thermal Evaluation under Normal Conditions of Transport

Section 2.1.3.2.1, “Thermal Analysis for RCT and NCT,” of the application describes an analysis of the DN30 package with: 1) an ambient temperature of 38°C (100°F) and no insolation, and 2) an ambient temperature of 38°C (100°F) with insolation. The staff finds that this meets the ambient temperature requirement in 10 CFR Part 71.71(c)(1).

The applicant described that the computer software ANSYS Workbench version 19.0 is used for the thermal analysis. The applicant provided the maximum allowable temperature limits for the components of the DN30 and 30B cylinder for NCT in Table 52, “Admissible component temperatures of the package DN30,” of the application. Based on the staff’s review of the applicant provided temperature limits, the staff finds the limits to be acceptable.

The applicant provided emissivity and absorptivity values for the surface of the DN30 package for normal conditions in Table 60, “Heat transfer by radiation at the surface of the DN30 package,” of the application. Based on the staff’s review of the applicant provided emissivity and absorptivity values, the staff finds the values to be acceptable.

The applicant also provided a convective heat transfer correlation for normal conditions based on vertical planes. While the convection heat transfer correlation was for vertical flat planes, the applicant performed a sensitivity study to demonstrate that a reduction in the convection heat transfer correlation did not have a significant effect on the DN30 package temperatures. Based on the results of the sensitivity study, the staff finds the convection correlation to be acceptable for the DN30 package.

3.4.1 Heat and Cold

The applicant provided the insolation data for vertical surfaces and all other surfaces in Table 58, “Solar insolation data,” of the application. The staff compared the values in Table 58 of the application to the 10 CFR Part 71.71(c)(1) values and found the values in Table 58 to be slightly more conservative because the units in Table 58 of the application were in Watts per square meter (W/m^2) compared to gram calories per square centimeter ($g\text{-}cal/cm^2$) in 10 CFR Part 71.71(c)(1), and therefore are acceptable.

The applicant provided the maximum component temperatures for NCT in Table 64, "Temperatures at the DN30 packaged loaded with an empty, partially filled and filled 30B cylinder under RCT and NCT," of the application. Table 64 of the application shows that under 12 hours cycles of insolation followed by no insolation, that the maximum temperature of the 30B cylinder is 52°C (126°F), which is below the UF_6 melting point and therefore will remain solid during NCT. The applicant provided analysis results for an empty, partially filled, and filled 30B cylinder during NCT to demonstrate that for a range of filling conditions, the DN30 package component temperatures remain below admissible temperature limits. The staff finds that the component temperatures in Table 64 of the application are below the admissible temperature limits in Table 52 of the application, and therefore are acceptable.

The applicant reported the maximum accessible surface temperature of the DN30 PSP during NCT is 38°C (100°F) from Table 64 of the application, which is less than 50°C (122°F) and therefore, the staff concludes this meets the requirements of 10 CFR 71.43(g).

The applicant specified in Section 1.2.7, "Lowest Transport Temperature for which the Package is Designed," of the application that the components were good to -40°C (-40°F). The staff's finding that the components are good to -40°C (-40°F) is described in Section 3.2.2, "Component Specification," of this SER.

3.4.2 Maximum Normal Operating Pressure

Section 1.2.8, "Maximum normal operating pressure," of the application describes the maximum normal operating pressure for the DN30 package is defined as the pressure at the triple point of UF_6, which is equal to 152 kPa (22.05 psig). The design pressure of the 30B cylinder is specified in ANSI N14.1, which is equal to 1.38 MPa (200 psig) at (121 °C) 250 °F. The applicant described in Section 1.4.2.3.1, "Pressure envelope of the DN30 package," of the application that the DN30 PSP is not designed as a pressure retaining component.

3.4.3 Maximum Thermal Stresses

The applicant described in Section 2.2.1.6, "Analysis of stresses caused by temperature influences," of the application that the gaps between the 30B cylinder and the inner shell of the DN30 PSP are sufficient to avoid development of thermal stresses. The staff finds that the applicant's evaluation of differential expansion and thermal stresses was adequate for NCT.

3.5 Thermal Evaluation under Hypothetical Accident Conditions

Section 2.2.2.3.3.2, "Results of the benchmark analysis," of the application summarizes how the measured data from the two fire tests compared to the calculated thermal analysis temperatures. The applicant described that the valve and plug calculated thermal analysis temperatures and benchmark fire tests were in good agreement, there was a greater difference between results for the mantle of the 30B cylinder due to the temperature sensor locations. \

Based on the staff's review of Section 2.2.2.3.3.2 of the application and the thermal fire test reports in Appendix 2.2.2.2, "Fire Test of a Previously Damaged Prototype of a DN30 Package," the staff finds that the HAC thermal analysis results have been acceptably benchmarked with the thermal fire tests.

3.5.1 Initial Conditions

Section 2.2.2.3.2.1, “Initial temperatures,” of the application describes that for the HAC fire analysis the initial temperatures is uniformly 63 °C (145 °F). The staff finds that this complies with the maximum temperature calculated during NCT for the DN30 PSP outer shell in Table 64, “Temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder under RCT and NCT.”

3.5.2 Fire Test Conditions

Section 2.1.3.2.2, “Thermal analysis for HAC,” of the application describes an analysis of the DN30 package with an ambient temperature of 800 °C (1475 °F) for 30 minutes. The applicant also described that in Section 2.2.2.3.5.1, “Temperatures at the DN30 package for full and partially filled 30B cylinders,” of the application that the post fire cooldown has an ambient temperature of 38 °C (100 °F) and solar insolation as defined in Table 58, “Solar insolation data,” of the application.
The applicant provided emissivity and absorptivity values for fire, and post-fire conditions in Table 60, “Heat transfer by radiation at the surface of the DN30 package,” that the staff finds meets the requirements in 10 CFR Part 71.73(c)(4). The applicant also provided a convective heat transfer correlation for accident conditions, as well as a pool fire gas velocity based on the recommended range provided in paragraph 728.30 from IAEA Specific Safety Guide SSG-26, “Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition).” While the convection heat transfer correlation was for vertical flat planes, the applicant performed a sensitivity study to demonstrate that a reduction in the convection heat transfer correlation did not have a significant effect on the DN30 package temperatures. The staff finds the criteria above meets 10 CFR Part 71.73(c)(4).

3.5.3 Maximum Temperatures and Pressures

The applicant described in Section 2.2.2.1.4 of the application describes the maximum internal pressure in the 30B cylinder is 2.57 MPa (373 psig) during HAC which takes into account any pressure increase due to the melting of UF_6 and remains below the valve test pressure 2.76 MPa (400 psig) described in ANSI N14.1, and therefore the staff finds the calculated HAC pressure is acceptable.

The applicant also concluded in Section 2.2.1.5.3.2, “Pressure development due to the expansion of the intumescent material,” of the application that the expansion of the intumescent material will not damage the 30B cylinder valve or plug.

The applicant provided the maximum allowable temperature limits for the components of the DN30 and 30B cylinder for HAC in Table 52, “Admissible component temperatures of the package DN30,” of the application. The applicant provided the maximum component temperatures in Table 65, “Maximum temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder,” of the application and based on the staff’s comparison of the temperatures in Table 65 to the maximum allowable temperature limits in Table 52 of the application, the staff finds the temperatures to be below the allowable limits.

In addition, the two thermal fire tests showed that the temperatures reached on the prototype DN30 packages did not have a negative effect on the function of the inner and outer shell of the

DN30 PSP with respect to criticality, and did not have a negative effect on 30B cylinder containment function.

Therefore, based on the staff's review of the thermal HAC analysis results that were benchmarked to the thermal fire tests described in Appendix 2.2.2.2, "Fire Test of a Previously Damaged Prototype of a DN30 Package," the staff finds 10 CFR 71.73(c)(4) is met.

3.5.4 Maximum Thermal Stresses

The applicant described in Section 2.2.1.6.1.3, "Stresses caused by temperatures reached during HAC," of the application that during the fire the DN30 shells heat up faster than the foam, which therefore increases the gap between both shells. The applicant also described that during the fire, portions of the foam incinerate, causing the foam to partly lose its structural integrity.

Therefore, the staff accepts that no thermal stresses will develop after the fire. The staff finds that the applicant's evaluation of differential expansion and thermal stresses was adequate for HAC.

3.6 Appendix

The applicant provided three appendices that detailed: 1) the thermal test program (Appendix 2.2.2.1, "Thermal test of the DN30 Overpack,") 2) the thermal test report (Appendix 2.2.2.2, "Fire Test of a Previously Damaged Prototype of a DN30 Package,") and 3) the thermal analysis (Appendix 2.2.2.3, "Thermal Analysis of the DN30 Package for the Transport of Uranium Hexafluoride").

For example, Appendix 2.2.2.1 provided descriptions of the thermal fire test preparation, initial conditions, support structure, and description of the BAM test facility. Appendix 2.2.2.2 provided descriptions of the thermal test preparations, weather conditions during the thermal fire tests and cooldown, the thermal fire tests, and results. In addition, Appendix 2.2.2.3 provided a detailed description of the thermal analysis.

The staff reviewed the appendices 2.2.2.1 through 2.2.2.3 and found the content to be supportive to the information provided Section 2.2.2, "Thermal Analysis," of the application.

3.6.1 Description of Test Facilities

The applicant provided details of the thermal test facilities in Appendix 1, "Description of the BAM Test Facility for Fire Tests in Horstwalde," of Appendix 2.2.2.1, "Thermal test of the DN30 Overpack," of the application. Based on the staff's review of this information, the staff found the content provided an adequate description of the thermal test facilities.

3.6.2 Test Descriptions

The applicant provided descriptions of the thermal fire tests in Section 4, "Performing Tests and Test Results," of Appendix 2.2.2.2, "Thermal Test Report," of the application. Based on the staff's review of this information, the staff found the content provided an adequate description of the two thermal fire tests.

3.7 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the thermal design has been adequately described and evaluated, and that the thermal performance of the package meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

The objective of the review was to verify that the DN30 package's containment design was adequately described and evaluated under normal conditions of transport and hypothetical accident conditions, as required per 10 CFR Part 71. Regulations applicable to the containment review include 10 CFR 71.31, 71.33, 71.35, 71.43.

4.1 Description of Package System

The Model No. DN30 package is a Type A(F) package for fissile material, specifically, for the transport of 30B cylinders, containing UF_6, designed and fabricated (including material selection) in accordance with the ANSI N14.1 standards.

The packaging consists of the DN30 PSP overpack that holds a 30B cylinder during transport and provides structural and thermal protection of the 30B cylinder during normal and accident conditions. The DN30 PSP includes a valve protecting device and a plug protecting device that act as barriers to prevent contact of the 30B cylinder's valve and plug with other parts of the DN30 PSP during accident conditions.

According to Table 6 of the application, the plug protecting device and the closure device meet ASME and DIN EN standards. As described in Section 1.4.2.3.4 of the application, six mortise-and-tenon closure devices ensure the 30B cylinder remains within the DN30 PSP, and therefore, cannot be accessed during transport. In addition, Section 1.7.4.2 indicated that shipping seals are installed after the mortise-and-tenon devices are secured with bolts.

The DN30 is designed for transport by road, rail, sea, and inland waterways; it was noted that transport by air of the fissile content is not permitted and this is also a condition of the CoC. The applicant notes, in Section 1.3.1, that UF_6 would have no more than 5% enrichment of commercial grade U-235 with natural isotopic composition. The 2277 kg of UF_6 have less than (or equal to) one A_2 quantity of activity with no plutonium being present, as stated in Section 1.6.7. Additional content details are listed throughout Section 1.3 of the application.

4.2 Description of Containment Boundary

According to Section 1.4.3, the containment boundary is the 30B cylinder, designed in accordance with ANSI N14.1, a consensus standard for UF_6 cylinders. The containment boundary consists of the 30B cylinder and heads and their welds, the valve body and stem including the threaded connection between the valve and the 30B cylinder, and the plug including the threaded connection between the plug and the 30B cylinder. There is no feature that allows continuous venting during transport.

According to drawing 30B-DAH-SOC-01-Rev5, the 30B cylinder is designed and fabricated according to Section VIII, Division I (ed. 2013), ANSI N14.1 (2012). Likewise, the application states, in Section 1.4.2.1, that the 30B cylinder is as specified in ANSI N 14.1 and provides additional details in Tables 4 and 5 of the application.

4.3 Pressurization of Containment Vessel

Section 1.2.8 of the application indicated that the maximum normal operating pressure for the 30B is 152 kPa (0.152 MPa), which is based on the triple point of UF_6. This pressure is less than the 1.38 MPa (gauge) design pressure (at 121°C) reported in the 30B cylinder drawing 30B-DAH-SOC-01 Rev. 5.

Likewise, Section 2.2.2.1.4 indicated the pressure during the hypothetical accident condition thermal test is 2.57 MPa. There is margin at this HAC pressure, and temperature, according to the discussion presented in Section 2.2.2.4.1 of the application, which also considered the 30B cylinder's hydrostatic test pressure of 2.76 MPa that is reported in drawing 30B-DAH-SOC-01 Rev. 5.

4.4 Containment Criteria

Section 1.3.1 of the application indicated that the content has less than one A_2 activity. Although the low activity does not necessitate a leakage rate for hypothetical accident conditions, the applicant stated in Section 2.2.3.3 that the cylinder would be leak tested with an acceptance criterion of 10^{-4} Pa.m^3/s standard leakage rate (SLR) to ensure releases would be below the 10^{-6} A_2/hr release acceptance criterion listed in Section 2.2.3.1. According to Section 1.7.2, the leakage rate tests are in accordance with ANSI N14.5. It is noted that, according to Section 2.1.1.3 of the application, the presence of the DN30 PSP is not considered in the containment analysis.

4.5 Compliance with Containment Criteria

Section 2.2.1.5 of the application described a series of drop tests (e.g., inclined orientation onto valve side corner, inclined orientation onto plug side corner, flat orientation onto valve) as part of the package's hypothetical accident condition analyses. Results showed that the closure systems were intact after each drop test. In addition, there was no contact of the valve cylinder or the plug with the DN30 PSP. Likewise, helium leakage rate tests were performed before and after each drop test.

According to Table 69 of the application, the leakage rate varied from 4.94 10^{-9} Pa.m^3/s SLR to 4.15 10^{-6} Pa.m^3/s SLR; measurements were well below the 10^{-4} Pa.m^3/s SLR acceptance criterion. The RAI 4.2 response (document 0023-BAR-2019-001-Rev1) showed that the helium leakage rate tests, before and after each hypothetical accident test, consisted of the entire 30B cylinder being enclosed and enveloped by helium.

Regarding the thermal accident test condition, the leakage rate after the thermal test was measured as 6.63 10^{-9} Pa.m^3/s which is well below the 10^{-4} Pa.m^3/s SLR leakage rate acceptance criterion.

It is also noted that Table 62 indicated that the 122°C maximum valve temperature was less than 131°C temperature reported in Section 2.2.2.1.4 of the application. As noted in Section 2.2.2.1.4, the 30B cylinder is designed according to ANSI N14.1 and, thus, is designed for a temperature range of -40°C to 131°C. Likewise, Section 2.2.1.5.3.2 of the application indicated that the cylinder, valve, and plug are not damaged due to the expansion of the intumescent material during the thermal test.

Section 2.2.3.6 noted that the above mentioned low leakage rates at hypothetical accident conditions bound the leakage rates expected under normal conditions of transport because of the greater severity of the hypothetical accident condition tests. In addition, the application indicated, in Section 2.2.1.4.2.1, that analyses and tests showed that there was no contact between the valve or the plug with any part of the DN30 PSP after the 1.2 m drop test. The SER's Structural Evaluation discusses the effect of reduced and increased external pressures on the package.

Although the content does not have an activity greater than A_2, the application noted in Section 2.2.3.1 that the Type A(F) package would have a release limit acceptance criterion of 10^{-6} A_2 /hr. The low measured hypothetical accident condition leakage rate values listed above are well below the manufacturing, maintenance, and pre-shipment leakage rate test acceptance criterion of 10^{-4} Pa.m^3/s SLR that was referred to in Section 1.7.2 of the application, and also stated in DNT response to RAI 4.1, document 0023-BAR-2019-Rev.1. According to Section 1.7.2.1, the leak test method complies with ANSI N14.5.

The response to RAI 4.1 (document 0023-BAR-2019-001-Rev1) stated that the 30B cylinder is leak tested after manufacturing and during recertification to a 10^{-4} Pa.m^3/s SLR acceptance criterion. Likewise, Section 1.8.2 of the application stated that the 30B cylinder's 5-year periodic inspection includes performing a hydrostatic strength test according to ANSI N14. In addition, a 100 psig pneumatic leak test, as described in ANSI N14.1, would be performed after installation of a new valve or plug.

4.6 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the containment design has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The staff reviewed the application to use the Daher DN30 package to transport commercial grade UF_6 as a type AF package and verified that the package criticality safety design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This review also considered whether the package is consistent with the acceptance criteria in Section 6 (Criticality Review) of NUREG-1609, Standard Review Plan for Transportation Packages for Radioactive Material."

6.1 Description of Criticality Design

Staff reviewed both the general information chapter in the DN30 application and the information presented in the criticality safety chapter. The package consists of an ANSI N14.1 certified 30B UF_6 cylinder contained within a DN30 protective structural package (PSP) to protect the cylinder during shipment. The DN30 package is a simple steel clamshell design with polyisocyanurate rigid (PIR) foam and a 10mm layer of thermal insulation between the inner shell and the PIR. No internal neutron absorbers are within the package design. Each DN30 package can accommodate one filled 30B UF_6 cylinder per package.

6.2 Fissile Material Contents

The allowable fissile material contents to be transported in the DN30 are enriched natural uranium in the form of UF_6 enriched to a maximum of 5.0 weight percent (wt%) ^{235}U, as specified in Table 1 of DAHER report 0023-BSH-2016-001, Appendix 2.2.5, Rev.1.

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configuration

The configuration proposed for the DN30 would allow one 30B UF_6 cylinder seated in the clamshell of the overpack. The applicant evaluated UF_6 at 5.0 wt% ^{235}U in various conservative configurations that investigated filled cylinders, partially filled cylinders, and potential voids within the 30B cylinder.

The density of the UF_6 was varied between expected material densities and the theoretical maximum density of 5.5 g/cm^3. The axial and radial dimensions of the criticality model are the same for both NCT and HAC. Models ignored the protrusions on the ends of the 30B cylinder (i.e., valve, valve skirts, and plugs) and modeled them conservatively as flat to minimize spacing. Water is assumed to penetrate the gap between the 30B cylinder and the inside of the DN30 package, as well as in the PIR foam on the interior of the package.

Consistent with good modeling practices, the applicant used the flat cylinder model to determine the most reactive baseline model of the DN30 package containing a 30B cylinder and built subsequent more realistic and more conservative models based on that analysis. Conservatisms in the model include the actual curved ends of the 30B cylinder, various fill levels of the cylinder, voids within a filled cylinder, impurities in the UF_6, inhomogeneity of the UF_6, optimum spacing of fissile material, conservative DN30 PSP modeling, analysis of gaps between the DN30 PSP and 30B cylinder, full water reflection, and orthogonal and hexagonal arrays of packages to justify the most reactive conditions for each model.

Staff evaluated the modeling methods used by the applicant, the material inputs, modeling dimensional tolerances, water reflection and moderation, and the representative input files submitted by the applicant and based on the numerous conservatisms demonstrated in the applicant's criticality analysis, found them to be sufficiently conservative for determining the maximum k_{eff} of the loaded DN30 package.

6.3.2 Material Properties

Staff verified that the applicant identified all relevant material properties of the DN30 transportation package and the intended fissile material to be transported. For the UF_6, the applicant considered pure UF_6 at an enrichment of 5.0 wt% ^{235}U and varied the density between 3.1 g/cm^3 and 5.5g/cm^3 (maximum theoretical density of UF_6). The applicant also analyzed UF_6 with a purity of 99.5 wt% UF_6 with 0.5 wt% Hydrogen Fluoride (HF), as well as any additional impurities that could potentially be present with repeated uses of the 30B cylinders (namely hydrogenated uranium residues [HUR]), at the same density range.

HUR are formed during repeated use of the 30B cylinders and are a result of the interaction of UF_6 with ambient water vapor during normal operations. These HUR result in compounds that create hydrogen bearing compounds within the 30B cylinders, namely uranyl fluoride (UO_2F_2) that is attached to H_2O. The applicant used several different references to obtain a bounding HUR content of UO_2F_2-5.5H_2O at an H/U ratio of 11, which staff determined to be conservative for use throughout the applicant's analysis.

6.3.3 Computer Codes and Cross Section Libraries

The applicant used the SCALE 6.0 and SCALE 6.1.1 code packages with the ENDF/B-VII cross-section set to develop their models to evaluate the maximum reactivity of the DN30 package. The SCALE code system is a standard in the nuclear industry for performing Monte Carlo criticality safety and radiation shielding calculations and has been used extensively for calculating the subcriticality of UF_6 systems. Staff evaluated the applicant's use of the codes, materials used in the models, and modeling methodology and found that the computer codes and cross-sectional libraries were conservative and appropriate for use in their calculations.

6.3.4 Demonstration of Maximum Reactivity

For the criticality evaluation of both NCT and HAC conditions of the DN30 package, the maximum reactivity configuration was determined through a series of computational models of various potential conditions of the package. These studies included maximum enrichment, potential impurities, HUR, full and partial filling of a 30B cylinder, and variations in UF_6 density.

Although the 30B cylinders are not expected to allow intrusion of water into the cylinder in either NCT or HAC, the applicant evaluated the potential for small amounts of water in-leakage and demonstrated that they are bounded by the conservative assumptions for HUR within the 30B cylinder.

6.4 Single Package Evaluation

The DN30 single package configuration was evaluated for all probable design variations, including variation of the outer dimensions of the 30B cylinder, the wall thickness tolerances, density of UF_6, UF_6 compositions, fill level in the cylinder, voids within the cylinder, thickness of the stainless steel shells of the DN30 package, and thickness of the gap between the package shells and the cylinder.

The most reactive condition was when the UF_6 contained an impurity of 0.5% HF at the maximum theoretical density of UF_6, and yielded a $k_{eff} + 3\sigma = 0.6101$, well below the administrative limit of $k_{eff} + 2\sigma = 0.95$.

Based on the analysis performed by the applicant demonstrating the reactivity of the various single package conditions, staff found that the single package is sufficiently subcritical.

6.5 Evaluation of Package Arrays under NCT and HAC

For the NCT and HAC, the applicant assumed an infinite hexagonal array with no PIR foam and no steel shells of the DN30 PSP to increase the interaction between packages in the package array evaluations. The applicant also performed calculations with the shells, as well as with the shells compacted into a single layer, to ensure that in the presence of voids within the 30B cylinder the DN30 would remain subcritical.

The applicant's analysis included variations in the gap size between adjacent cylinders, the water density and gap size between adjacent cylinders, the water density in the gap and gussets between adjacent cylinders, the UF_6 composition, fill level, voids, and exterior dimensions and wall thickness of the 30B cylinders as was done for the single package evaluations.

The applicant also performed an extensive study of realistic and theoretical inhomogeneous distributions of UF_6 and potential impurities, including arranging the impurities into the most reactive geometric configuration and relative locations to maximize the reactivity of the array system. In all cases, water intrusion into the 30B cylinder was not incorporated into the evaluation since the water immersion tests performed by the applicant showed no leakage.

Also, Section 6.7 of DAHER report 0023-BSH-2016-001, Appendix 2.2.5, Rev.1 found that a small amount of water intrusion was bounded by the assumed amount of volatile hydrogenous material and HUR. Staff reviewed the references provided by the applicant (MILIN 2016, CONNOR 2013, BEGUE 2013, and REZGUI 2013) that were used in making this determination and found that this assumption is valid for use within the DN30 PSP.

For all array calculations, the applicant analyzed the various configurations to determine the most reactive configurations while applying all of the assumptions listed above. The most conservative realistic configuration was found to be an infinite array of DN30 packages with a 30B cylinder minimal wall thickness of 0.794 cm for a completely filled cylinder containing almost twice the allowable mass of UF_6 as specified in ANSI N14.1, and only taking into account the steel shells of the DN30 PSP. This configuration bounded all partially filled cylinders with a greater wall thickness, and yielded a $k_{eff} + 3\sigma = 0.9351$. Other bounding calculations included an infinite array of 30B cylinders with no DN30 PSP surrounding it, with a central void occupying approximately 50% of the internal space, which yielded a $k_{eff} + 3\sigma = 0.9422$.

The most conservative evaluated case was an infinite array of 30B cylinders without the DN30 PSP with a hypothetical arrangement of a sphere of UO_2F_2-5.5 H_2O impurities surrounded by UF_6 and a spherical shell of HUR, and resulted in a maximum $k_{eff} + 3\sigma = 0.9493$, which remained below the administrative limit of $k_{eff} + 2\sigma = 0.95$.

Staff reviewed the sample input decks provided by the applicant and found them accurate and conservative for analysis of 30B cylinders both with and without the DN30 PSP, and found that 30B cylinders transported within the DN30 PSP would be adequately subcritical for all expected transport conditions.

6.7 Benchmark Evaluation

The applicant provided an updated validation discussion based on staff's RAI 6.3 (DAHER letter 0023-BAR-2019-001) that extended the benchmarking analysis with additional UF_6 compound benchmark experiments. The new trending of k_{eff} results with the ^{235}U enrichment and the energy of the average lethargy of fission with the addition of benchmark series LCT-033 determined that the bias of Δk rose from 0.0 to 0.0129.

This increase in the bias was incorporated into the analysis of the DN30 package described in Section 2.2.5.5.3.3 of the application and in Section 9.8.7 of Appendix 2.2.5. These changes place the evaluation of the DN30 PSP within the area of applicability of the validation and bounds the analyses performed by the applicant.

6.8 Evaluation Findings

The staff evaluated the criticality safety analysis for DN30 packages that are loaded with 30B cylinders containing UF_6 and has the following evaluation findings:

- Staff found that the DN30 package description and evaluation for the transport of 30B cylinders enriched up to 5 wt% ^{235}U provided an adequate basis for the criticality evaluation.
- Staff found that the description of the DN30 fissile material contents provided an adequate basis for the criticality evaluation.
- Staff found that the criticality description and evaluation of the DN30 PSP package with 30B cylinders as contents addresses the criticality safety requirements of 10 CFR Part 71.
- Staff found that the criticality evaluation of a single package is subcritical under the most reactive credible conditions.
- Staff found that the criticality evaluation of the most reactive infinite array was subcritical under NCT and HAC.
- Staff found that the benchmark evaluation of the calculations were appropriate for the evaluation of the DN30 PSP.

Based upon the information provided by the applicant, the staff has reasonable assurance that the applicant's criticality analyses demonstrate that the package design meets the criticality safety requirements in 10 CFR Part 71.

6.9 Conclusion

The staff evaluated the assumptions used by the applicant and the modeling methodology used in determining the subcriticality of the DN30 PSP loaded with a 30B cylinder for all NCT and HAC configurations. The applicant used straightforward computer modeling, conservative assumptions in materials and configurations of fissile material, moderators and reflectors, broad parametric studies of perturbations of the modeled system to cover all credible conditions of the DN30 PSP, and sound engineering practice in their evaluation.

Based upon the information provided by the applicant and staff's review of the configurations and maximum k_{eff} values presented in the application and responses to RAIs from staff, the staff has reasonable assurance that the applicant's criticality analyses demonstrate that the package design meets the criticality safety requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATING PROCEDURES

The application provides a description of package operations, including package loading and unloading operations, and the preparation of an empty package for shipment. Loading and unloading procedures show a general approach to perform operational activities because site-specific conditions may require the use of different equipment and loading or unloading steps.

The following documents are part of the application: "Handling Instruction No. 0023-HA-2015-001-Rev 2", "Periodical Inspections of DN30 PSP, Test Instruction 0023-PA-2015-015-Rev 1" and, "Inspection Criteria and Maintenance of the DN30 PSP, Test Instruction, 0023-PA- 2015-016-Rev 1".

The package operating procedures are contained in the document titled: "Use and Handling of the DN30 PSP" (0023-HA-2015-001-Rev 2). The package is intended to be transported by rail or truck trailer.

The applicant described three different ways to lift the package when carrying contents and, when empty, described the preparations, inspections, and cautions that should be taken when handling the 30B cylinder, and how to install it within the PSP. These instructions are both provided in a graphical and written format.

Specifically, when the package is loaded with a 30B cylinder and lifted by all four feet, the applicant describes the angle of the slings as having to be less than 60^{o} (depicted graphically in (0023-HA-2015-001-Rev 2). The applicant also states that lifting chains are not allowed as they may damage the PSP, and that the slings themselves must be rated for 2,500 kg each. The applicant also describes the orientation of the slings when just the top of the package is lifted, and their lifting capacity. The applicant describes the manner in which the closure devices, located at six locations on the PSP, are to be locked and torqued.

The applicant describes the procedures used to tie the package to the conveyance (flat track). The procedures to install the bolts connecting the feet of the PSP to the conveyance is described along with the applicable torque. The applicant states that calculations need to be submitted and approved in order to tie the PSP down via straps.

The NRC staff has reviewed the description of the operating procedures and finds that the package will be prepared, loaded, transported, received, and unloaded in a manner consistent with its design and evaluation for approval. The NRC staff has reviewed the description of the special instructions to inspect and handle the 30B cylinder, and to safely open a package and concludes that the procedures for providing the special instruction to the consignee are in accordance with the requirements of 10 CFR 71.89.

Testing requirements and controls before each transport, including inspecting the 30B cylinder before filling and before loading the 30B cylinder into the DN30 PSP, are to be carried out in accordance with ANSI N14.1 and, at least, as described in USEC 651 (or equivalent plant specific instructions). For example, the 30B cylinder is weighed before and after filling to avoid overfilling. In addition, before loading into the DN30 PSP, the 30B cylinder is inspected to ensure there are no deposits at the valve or plug.

Likewise, the 30B cylinder is cooled after filling such that the vapor pressure within the 30B cylinder is below atmospheric pressure and, as noted in Section 1.7.4, UF_6 contents are in a solid state. Section 1.7.2 of the application also stated that the closure of the valve seat of a filled 30B cylinder is to be verified by leak testing the pigtail before disconnection, and after closing the cylinder valve seat. The leak test method, such as an air pressure test or a vacuum test, is to comply with ANSI N14.5 with an acceptance criterion of the leak test of 10^{-4} Pa.m^3/s SLR.

The response to RAI 4.1 (document 0023-BAR-2019-001-Rev1) stated that the 30B cylinder is leak tested after manufacturing and during recertification to a 10^{-4} Pa.m^3/s SLR acceptance criterion. Likewise, Section 1.8.2 of the application stated that the 30B cylinder's 5-year periodic inspection includes performing a hydrostatic strength test according to ANSI N14.

In addition, a 100 psig pneumatic leak test, as described in ANSI N14.1, would be performed after installation of a new valve or plug.

The staff reviewed the Operating Procedures in Section 1.7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation. On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures provide adequate measures and reasonable assurance for safe operation of the package in accordance with 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

As part of the review, the staff also looked at the descriptions of the acceptance tests and maintenance programs to ensure they are acceptable and appropriate for the package.

The maintenance of the DN30 packaging and checks before each use are described in the handling instruction No. 0023-HA-2015-001 (see Appendix 1.7.1 (Handling Instruction)). This handling instruction references test instruction No. 0023-PA-2015-016 (see Appendix 1.8.2 (Inspection Criteria)) in which the criteria for the checks are defined and measures in case of non-conformances or deviations are specified.

In the case that non-conformances or deviations might affect the safety of the DN30 packaging the user of the packaging has to inform the CoC holder in writing about the non-conformance or deviation. The CoC holder has to report any non-conformance to the NRC with a 71.95 report and implement all necessary measures to return the packaging to service in full compliance with the CoC conditions.

The periodical inspections of the DN30 packaging are subdivided into the periodical recertification of the 30B cylinder and the periodical inspection of the DN30 PSP. The recertification of the 30B cylinder is regulated in ANSI N14.1, and there are no additional requirements for the use of the 30B cylinder as part of the DN30 packaging.

The periodical inspections of the DN30 PSP are described in test instruction Nos. 0023-PA2015-015 and 0023-PA2015-016. Staff requested some clarifications and, in particular, that items inspected will be replaced if the inspection shows excessive wear or any defects. Handling Instruction No. 0023-HA-2015-001 has been updated to prescribe the replacement of the items specified in step L.8 before loading a 30B cylinder, if the visual inspection shows excessive wear and/or defects.

The staff reviewed the acceptance tests and maintenance programs and found them acceptable. Based on the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71.

CONDITIONS

The following conditions are included in the Certificate of Compliance:

(a) The package shall be prepared for shipment and operated in accordance with the Operating Procedures of Chapter 1.7 of the application.

(b) Each packaging must meet the Acceptance Tests and Maintenance Program of Chapter 1.8 of the application.

(c) Packagings in which stainless steel components show pitting, corrosion, cracking, or pinholes are not authorized for transport.

(d) The 30-inch diameter UF6 cylinder valve and plug threads may be tinned with ASTM B32, alloy 50A or Sn50 solder material, or a mixture of alloy 50A or Sn50 with alloy 40A or Sn40A material, provided the mixture has a minimum tin content of 45 percent.

(e) Transport by air is not authorized

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. DN30 package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9362, Revision No. 0,
on July 25, 2019.