SAFETY EVALUATION REPORT
Docket No. 71-9388
Model No. DN30-X Package
Certificate of Compliance No. 9388
Revision No. 0

SUMMARY

By letter dated June 29, 2021 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML21181A000), DAHER NUCLEAR TECHNOLOGIES GmbH (DNT) submitted an application for approval of the Model No. DN30-X package for shipment of uranium hexafluoride with an enrichment up to 20 percent (%). The Nuclear Regulatory Commission (NRC) staff performed an acceptance review of the application and, on October 8, 2021, Orano NCS GmbH (after the September 30, 2021, acquisition of DNT by Orano) responded to staff's September 22, 2021, request for supplemental information (ML21281A046).

On October 19, 2021, the application was accepted for a detailed review (ML21291A064).

Staff issued a request for additional information (RAI) by letter dated June 10, 2022. Orano NCS GmbH provided responses to staff's RAIs on September 9, 2022, and submitted a revised application (Revision No. 2) including additional calculations, explanations and clarifications in addition to the RAI responses (ML22252A083).

On November 23, 2022, Orano NCS GmbH submitted a design change in the orientation of the criticality control system for both the 30B-10 and 30B-20 cylinders, to allow the insertion of a flexible lance through the valve opening, to facilitate cylinder washing operations. At that time, ORANO NCS GmbH provided for staff's review Revision No. 3 of the application (. ML22327A180)

On February 9, 2023, Orano NCS GmbH submitted page changes, limited to section 7.2.8 of appendix 2.2 of the safety analysis report (SAR), to resolve a disconnect, noted by staff during its final review, between the design drawings and the structural analysis, i.e., replacing an initial weld specification of a 6 x 10 mm step weld with a weld of 2 x 30 mm.

On February 24, 2023, staff was officially informed that, due to the acquisition of DNT by Orano Nuclear Packages and Services, Orano NCS GmbH was to be de facto the Certificate of Compliance (CoC) holder for the Model No. DN-30X package. Orano NCS GmbH holds an established quality assurance program and implementing procedures for compliance to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71, "Packaging and Transportation of Radioactive Material," and 10 CFR Part 21, "Reporting of Defects and Noncompliance". As such, the CoC for the Model No. DN30-X package is being issued to Orano NCS GmbH.

The Model No. DN30-X package was evaluated against the regulatory standards in 10 CFR Part 71, including the general standards for all packages and the performance standards specific to fissile material packages under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). This review also considered whether the package is consistent with the acceptance criteria of NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material."

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.

EVALUATION

1.0 GENERAL INFORMATION

The Model No. DN30-X package consists of the DN30 protective structural packaging (PSP), approved under Docket No. 71-9362 for the Model No. DN30 package, and the 30B-X cylinder. The “X” in DN30-X and 30B-X is either replaced by “10” or by “20” to refer to a specific design for a maximum enrichment of 10 or 20 wt.-% ^{235}U, respectively.

The 30B-X cylinder consists of a cylinder shell with an elliptical head on each end, a valve and plug half coupling. the cylinder valve and plug, two skirts attached to each elliptical head, where the skirt on the valve side has two horizontally aligned holes that are used to prevent the rotation of the cylinder inside the PSP, two criticality control system (CCS) restraints, each with a backing bar and a rotation preventing device, to maintain the position of the interior CCS within the cavity of the 30B-X cylinder.

The CCS consists of criticality control rods (CCRs) containing neutron poison material in the form of boron carbide (B_4C), and three lattice holders to keep each CCR in place. The separation of the lattice holders is maintained by 14 longitudinal stiffeners.

The lattice holders are entirely made of steel. The length of the CCRs is fitted to the elliptical heads of the 30B-X cylinder.

Of special note are the two CCRs that end in front of the valve because these are shortened to avoid any interference with the cylinder filling and emptying operations.

The 30B-10 cylinder (with a maximum enrichment of 10 wt.% ^{235}U) includes 33 CCRs while the 30B-20 cylinder (with a maximum enrichment of 20 wt.% ^{235}U) includes 43 CCRs. Apart from the B_4C filling, the CCS is made of carbon steel for low-temperature service, like the pressure envelope of the cylinder.

The permissible mass of UF_6 and the maximum heel quantities for each cylinder, DN30-10 and DN30-20, are listed below:

Permissible mass of UF_6 for each package design

Package design	Enrichment limit in wt.-% ^{235}U	Permissible mass of UF_6 in kg	Maximum heel quantities in kg
DN30-10	10	1460	11.3
DN30-20	20	1271	11.3

Both cylinders, DN30-10 and DN30-20, have a nominal length of 2,070 mm, a nominal diameter of 762 mm, a nominal wall thickness of 13 mm, and an identical nominal gross weight of 2,912 kg: the 30B-10 has a nominal tare weight of 1,452 kg and the 30B-20 has a nominal tare weight of 1,641 kg.

The PSP consists of the bottom half with welded to the outer shell for tie-down during transport, load attachment points for handling the loaded package, a valve protecting device attached to the bottom half with hinges, a plug protecting device welded to the interior shell of the bottom half, rotation preventing devices consisting of two pins welded to the flange of the bottom half, and bottom half of the closure devices.

The valve protecting device consists of a stainless-steel housing filled with polyisocyanurate rigid foam. It is shaped like a U and encloses the valve of the 30B-X cylinder during transport. It is connected to the bottom half of the PSP through two hinges. A protecting housing made of thin stainless-steel sheets is placed inside the U-shape of the valve protecting device.

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 PSP is fabricated in accordance with:

Drawing No. 0023-ZFZ-1000-000, Rev. 3 – DN30 PSP
Drawing No. 0023-ZFZ-1000-100, Rev. 0 – Closure Device
Drawing No. 0023-ZFZ-1100-000, Rev. 4 – 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. 3 – Valve Protecting Device

The 30B-10 Cylinder is fabricated in accordance with:

Drawing No. 0045-ZFZ-1000-000, Rev. 2 – 30B-10 Cylinder
Drawing No. 0045-ZFZ-1100-000, Rev. 1 – 30B Cylinder modified
Drawing No. 0045-ZFZ-1200-000, Rev. 2 – CCS

The 30B-20 Cylinder is fabricated in accordance with:

Drawing No. 0045-ZFZ-2000-000, Rev. 2 – 30B-20 Cylinder
Drawing No. 0045-ZFZ-1100-000, Rev. 1 – 30B Cylinder modified
Drawing No. 0045-ZFZ-2200-000, Rev. 2 – CCS

The staff reviewed the drawings and noted that they reference American National Standards Institute (ANSI) N14.1 for both welding and for materials. The staff asserts, for accuracy and completeness, that the 30B-10 and 30B-20 cylinders are not at this time designed, fabricated, inspected, tested and marked in accordance with the ANSI standard N14.1 that does not include them.

HALEU 10 and HALEU 20 are enriched from commercial natural UF_6 and comply with the isotopic limits below. The isotopic composition shall not exceed a Type A quantity.

Isotopic limits of UF_6 HALEU 10 and HALEU 20
Maximal concentration in wt.-% in uranium

Nuclide	HALEU 10	HALEU 20
^{232}U	3×10^{-8}	7×10^{-8}
^{234}U	1.2×10^{-1}	2.6×10^{-1}
^{235}U	10	20
^{236}U	5×10^{-2}	10^{-1}
^{238}U	balance	balance
^{99}Tc	10^{-6}	10^{-6}

The maximum quantity of material per package is indicated in the table below:

Package	Enrichment limit wt% ^{235}U	Mass UF_6 (kg)	Fissile material (kg)	Maximum heel quantity (kg)
DN30-10	10	1460	98	11.3
DN30-20	20	1271	170	11.3

Because this package is not in compliance with ANSI N14.1 nor American Society for Testing and Materials (ASTM) C996 “Standard Specification for Uranium Hexafluoride enriched to less than 5 wt. % ^{235}U” since its contents are greater than 5% enriched, the staff asked the applicant to detail the radioactive content specifications in SAR section 1.3.1.3 so that the contents would be perfectly defined. As such, the applicant has addressed the safety, health physics, and criticality requirements of the contents, in the section “General specification of UF_6 grade HALEU 10 and HALEU 20” with the following requirements:

(a) the UF_6 concentration shall not be less than 99.5g UF_6 per 100 g of sample to limit hydrogen content,

(b) the total hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon content shall not exceed 0.01 mole % of UF_6

(c) total absolute vapor pressure of content shall not exceed UF_6 industry standard values to prevent overpressure when heating,

(d) decay heat shall not exceed 3 W.

Those requirements are CoC conditions.

The applicant demonstrated that an infinite array of DN30-X packages, containing either a 30B-10 or 30B-20 UF_6 cylinder, will remain subcritical under NCT and HAC. The corresponding Criticality Safety Index (CSI) of the package is 0.

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-X package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL AND MATERIALS EVALUATION

The objective of the structural evaluation is to verify that the structural performance of the package meets the regulatory requirements of 10 CFR Part 71 (Reference 1).

2.1 Description of Structural Design

2.1.1 General

The DN30-X is a Type AF package and consists of the DN30 PSP that contains the 30B-X cylinder designed to carry uranium hexafluoride (UF_6) grade high-assay low-enriched uranium (HALEU). 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 which is used to tie down the package to a conveyance via bolts during transportation. The PSP portion of the package has both an outer and inner shell which is separated by an impact absorbing and fire-retardant foam material. Several attachments (lifting lugs) are located on the PSP to facilitate handling.

The 30B-X cylinder is a cylindrical vessel with ellipsoidal heads. The cylinder has valve and plug hardware which are attached to the heads and protected by skirts. The cylinder contains an integral criticality control system (CCS) which consists of an array of criticality control rods (CCRs) filled with neutron poison material. The position and orientation of the CCS are maintained by restraints welded at the inside junctions of the 30B-X cylindrical section and heads.

The applicant provided licensing drawings with tolerances, dimensions, welding symbols and definitions, material designation, and associated standards in the SAR (Reference 2). Component descriptions and the arrangement of components relative to each other are described in the SAR.

The applicant also provided the weight of the package with and without its contents as well as the overall physical dimensions of the package. The 30B-X cylinder and DN30 PSP package dimensions are presented in tables 1-13 and 1-14 of the SAR.

The NRC staff reviewed the package structural design description and determined that the contents of the application satisfy the requirements of 10 CFR 71.31(a), 71.33(a) and 71.33(b).

2.1.2 Materials

The materials of the DN30 PSP used in the DN30-X package are identical in construction to the materials of the DN30 PSP used in the DN30 package. The materials of construction for the DN30 PSP are specified in table 1-12 of the SAR with additional information in the DN30 SAR (Reference 3), which was previously reviewed and accepted by the NRC staff (Reference 4).

The 30B-X cylinder is composed of ASTM A516 Grade 65/70 carbon steel. The lattice holders and longitudinal stiffeners of the CCS are fabricated from ASTM A516 Grade 65/70 carbon steel. The CCRs are ASTM A333 Grade 9 seamless steel tubing with welded ASTM A516 Grade 65/70 steel lids.

The NRC staff's safety evaluation on the applicant's material evaluations are provided in the subsection "Materials Evaluations," of this SER chapter. The NRC staff determined that the package satisfies the regulatory requirements of 10 CFR 71.31(a).

2.1.3 Identification of Codes and Standards for Package Design

The NRC staff reviewed the codes and standards used by the applicant. The material standards used for the package comply with ASTM standards for the 30B-X cylinder. The cylinders are designed in accordance with Section VIII, Division 1 of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) (reference 6).

The material standards used for the outer portion of the package and the PSP use European standards with applicable ASTM equivalents. The applicant provided the relationship between the U.S. and international codes and standards.

The applicant used the LS-DYNA and ANSYS finite element (FE) computer programs to analyze the structural performance of the package. Forschungskuratorium Maschinebau (FKM) (reference 7) was used to analyze lifting and tie-down features, weld stresses, and perform fatigue analysis of the package components.

Material data and calculation formulas for minimum wall thickness of the pressure vessel were taken from the ASME BPVC code. Guidance on pressure calculations and allowable deformations of the UF_6 cylinder was taken from the manual for good handling practices for UF_6 (Reference 8). The NRC staff reviewed the codes and standards used in the package design and found them acceptable.

The NRC staff determined that the package satisfies the regulatory requirements of 10 CFR 71.31(c).

2.1.4 Minimum Package Size

The applicant indicated in section 1.4 of the SAR that the smallest dimension of the package is greater than 10 cm, which is larger than the requirements of 10 cm in 10 CFR 71.43(a).

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.43(a).

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 six locations. Each mortise and tenon system is locked in place by a pin, which secures both the top and bottom steel blocks, and the pin is then secured by a bolt.

The NRC staff reviewed the package description and confirmed that two sealing blocks are attached to the top and bottom half of the PSP to permit the installation of a high security seal as described in section 1.4.2.3.8 of the SAR. Furthermore, the pins and closure bolts of the mortise and tenon closure system are readily visible, and, if they are missing, it will indicate that the package has been tampered.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.43(b).

2.1.6 Positive Closure

The 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 six locations that secure the halves of the PSP together. The mortise and tenon system are locked in place by a pin at six locations.

As described in appendix 1.7.1 of the SAR, the pin in each of the six mortise and tenon devices is secured by bolts with Nord-Lock washers and defined tightening torques to provide positive closure. The NRC staff reviewed the package description and confirmed that these devices and torques provide a positive means of closure.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.43(c).

2.1.7 Package Valve

10 CFR 71.43(e) requires that a package valve must be protected against unauthorized operation. The only portion of the package that has a valve is the 30B-X cylinder which is nested within the PSP and is not accessible to any unauthorized operation. The NRC staff reviewed the package description and found that the valve is protected against unauthorized operation.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.43(e).

2.2 Lifting and Tie-Down Standards

2.2.1 Lifting Devices

The applicant described lifting and handling of the package in section 1.4.2.4 and section 2.2.4.3 of the SAR. The applicant stated that the lifting calculations for the DN30-X package are identical to those of the DN30 package since the gross weight of the 30B-X cylinder is the same as the gross weight of the 30B cylinder and the same PSP is used. The lifting and handling instructions are provided in appendix 1.7.1 and lifting calculations are provided in section 4.3.1 of the SAR, appendix 2.2.

The package can be lifted using three different methods that could directly affect the 30B-X cylinder: (1) lifting the package (PSP and 30B-X cylinder) via four lugs welded to the feet of the PSP, (2) lifting the package with a fork lift utilizing two specially made fork lift pockets located under the PSP body to carry both the PSP and 30B-X cylinder, or (3) lifting of the top lid portion of the PSP using two lifting lugs.

Of all three lifting methods, method (1) is the most limiting where a safety factor of 4.4 is calculated using nominal shear stress. Details are provided in table 4-1 of the SAR, appendix 2.2.

Based on the applicant’s analysis for lifting, the NRC staff concluded that the calculated safety margin is greater than 3.0 with respect to yielding; thereby, the package meets the requirements of 10 CFR 71.45(a) for lifting.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.45(a).

2.2.2 Tie-Down Devices

The applicant described the tie-downs of the package in section 1.4.2.5 and section 2.2.5.1 of the SAR. The applicant stated that the tie-down calculations for the DN30-X package are identical to those of the DN30 package since the gross weight of the 30B-X cylinder is the same as the gross weight of the 30B cylinder and the same PSP is used. The DN30-X tie-down calculations are provided in section 5.1 of the SAR, appendix 2.2.

The package is tied down via the feet of the package which are bolted to a dedicated flat rack. The tie-down calculations showed that the package can 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. The NRC staff reviewed and confirmed that the induced stresses in the tie-down system do not exceed the yield stress. Based on the review of the analyses, the NRC staff concluded that the results of the analysis are acceptable.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.45(b).

2.3 General Considerations for Structural Evaluation

The evaluation of the DN30-X package relied heavily on the calculations done for the DN30 package and documented in the DN30 SAR, which was previously reviewed and accepted by the NRC staff (reference 4). The applicant evaluated the DN30 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 and used this as a basis to develop a bounding set of analyses to evaluate the DN30-X. The applicant first performed a pre-analysis of the DN30 using the finite element method (FEM) tools to simulate drop testing, followed by physical testing of DN30 prototypes, followed by a refinement of the pre-analyses models to evaluate the DN30 package for additional analyses, followed by additional analyses of the DN30-X package to evaluate the interactions of the CCS and 30B-X cylinder. The structural analyses of the DN30 package drop tests is documented in Calculation Report 0023-BBR-2022-004.

The applicant performed additional analyses for the DN30-X package which included the 30B-X cylinder and CCS. These analyses considered a 10.2 m free drop which combines the height of a 1.2 m NCT drop, and a 9.0 m HAC drop. The applicant demonstrated from a physical test that the combined 10.2 m drop resulted in greater package damage for the corner drop test than the sequence of individual NCT and HAC free drops.

LS-DYNA models were used for three additional drop test orientations to evaluate the DN30-X package. The valve and plug were demonstrated to not experience contact with any other part of the packaging due to the protecting devices fulfilling their function, so the valve and plug would be protected during an NCT drop. Plastic strains were observed in the vicinity of the valve for the flat drop onto the valve end, but the amount of plastic strain that could be attributed exclusively to the NCT drop could not be determined. In response to a request for additional information from staff, the applicant completed an finite element analysis (FEA) for the NCT 1.2m end drop onto the valve side which demonstrated there are no plastic strains in the region of the cylinder valve. The additional calculation was adequately documented in the structural appendix 2.2.

2.3.1 Contents Modeling

The UF_6 content for the DN30 package was modeled as a single solid block within the 30B cylinder which matches the physical drop testing of the prototype that used concrete and steel as a surrogate test weight. For the LS-DYNA models, the applicant assumed that the 30B cylinder is lying on its side, and that the UF_6 fills 60% of the available volume in the cylinder. The applicant also considered the scenario where the 30B cylinder is filled to less than 50% of the volume within the 30B cylinder.

In the additional modeling evaluations for the DN30-X package, a three-dimensional UF_6 content within the 30B-X cylinder was not modeled explicitly in the LS-DYNA models due to the complexity of meshing, large model size, and uncertainties of the mechanical properties due to possible fractures within the solid content. The content weight was instead distributed between the surfaces of the 30B-X cylinder and/or the CCRs such that all the content mass was included but none of its structural rigidity was accounted for in the model. The staff found this approach acceptable to bound the interactions between the CCS and the 30B-X cylinder, as well as its effects on the impact stresses in the cylinder, CCS restraint, the CCRs, and the lattice holders.

The content weight was conservatively placed entirely on the CCRs for the corner drop (valve side) and flat drop (feet side) but was distributed between the 30B-X cylinder and CCRs for the flat drop to identify the sensitivity of the resulting 30B-X cylinder and CCS stresses.
The CCS restraint, lattice holder, and lattice stiffener were modeled with solid elements. The CCRs were modeled with solid elements to represent the neutron poison material and shell elements to represent the seamless pipe and welded lid.

The elastic-plastic material curve developed for the B30-X cylinder was also used for the CCR pipes, lattice holders, and longitudinal stiffeners. An elastic-perfectly plastic material curve with the properties shown in table 2-9 of the SAR was used for the B_4C neutron poison.

The staff reviewed the LS-DYNA models and free drop analyses for the DN30-X package and found no hourglassing issues.

2.3.2 LS-DYNA Model

The LS-DYNA FEM model was constructed for evaluation of the DN30-X package under NCT and HAC. Details of the model meshing for the PSP were provided in section 4 and table 4-3 of the Calculation Report 0023-BBR-2022-004 where the entire model was comprised of about 250,000 elements.

The LS-DYNA model for the DN30-X includes detailed representations of the PSP, 30B-X cylinder and CCS. The model for the 30B-X cylinder is comprised of about 456,000 elements. The details of the LS-DYNA model are described in section 2.2.7.1.2 of the SAR and section 7.2.3 of the SAR, appendix 2.2.

The LS-DYNA model used to simulate drop test conditions are composed primarily of shell elements with five integration points to capture plastic deformations and solid elements using default solid eight-node hexahedron elements. Beam elements are also used to model the sleeve to pin connection. The automatic single surface contact option is used to simulate standard contact between components with a friction value of 0.15 (dry steel to steel) and viscous damping of 20%.

Standard single surface sliding contact elements are used between the CCS and the 30B-X cylinder and restraints and between the neutron poison and the CCR pipes. Five different tied-contact types are used to simulate the various welded connections. Material properties are provided through vendor datasheets, physical testing, and tabulated values in relevant codes and standards in developing the LS-DYNA model.

The NRC staff reviewed the model descriptions and found that the LS-DYNA models is adequately developed to analyze the performance of the package under NCT and HAC and concluded that the model is acceptable.

2.3.3 ANSYS Model

The applicant used an ANSYS model to supplement the LS-DYNA model and demonstrated the structural safety of the closure device and the CCS restraint weld. The ANSYS model primarily used tetrahedral elements to explicitly model the closure device in detail.

The NRC staff reviewed the model descriptions and found that the ANSYS model is adequately developed to analyze the closure device under NCT and HAC and concluded that the ANSYS model is acceptable.

2.3.4 Benchmarking and Validation

Benchmarking of the LS-DYNA and ANSYS models against physical testing results for the DN30 was performed and documented in Calculation Report 0023-BBR-2022-004. Additional LS-DYNA model using the same approach was developed and used to analyze the safety features of the DN30-X package as documented in the SAR.

The applicant benchmarked and validated the FEM analyses using the LS-DYNA and ANSYS programs and the results of the physical model testing from appendix 2.2 (Drop Test Reports) as shown in Calculation Report 0023-BBR-2022-004 (Structural Analysis of Drop Tests for the DN30 Package under NCT and ACT). The applicant first performed preliminary calculations using the 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 to find a potential maximum damage to the plug protecting device, valve protecting device, the remaining parts of the 30B cylinder and closure system. The applicant demonstrated from a physical test that the combined 10.2 m drop resulted in greater package damage for the corner drop test than the sequence of individual NCT and HAC free drops. LS-DYNA models were used for three additional drop test orientations to evaluate the DN30-X package.

The valve and plug were demonstrated to not experience contact with any other part of the packaging due to the protecting devices fulfilling their function, so the valve and plug would be protected during an NCT drop. Plastic strains were observed in the vicinity of the valve for the flat drop onto the valve end, but the amount of plastic strain that could be attributed exclusively to the NCT drop could not be determined.

In response to a request for additional information from staff, the applicant completed an FEA for the NCT 1.2m end drop onto the valve side which demonstrated there are no plastic strains in the region of the cylinder valve. The additional calculation was adequately documented in the updated structural appendix 2.2.

The applicant used predicted deformations, decelerations, and content movement obtained from FEM analyses to validate the performance of the package. Physical testing used in the validation was based on five drop test sequences performed at the BAM facility in Germany. The applicant compared measured deformations and accelerations of the drop testing with the deformations and decelerations calculated from the LS-DYNA analyses.

The NRC staff reviewed the applicant’s approach taken for benchmarking and validation of the LS-DYNA and ANSYS models against physical testing results documented in Calculation Report 0023-BBR-2022-004, and additional LS-DYNA models developed to analyze the specific safety features of the DN30-X package as documented in the SAR, and found them acceptable to evaluate the structural performance of the DN30-X package under NCT and HAC.

2.3.5 Drop Test Campaign

A series of prototype physical drop tests were performed at BAM. Details such as specimen construction, drop orientation, video recording, sampling speed, test preparation, etc., are described by the applicant in the BAM drop tests report.

The DN30-X package uses the same PSP as the DN30 package used and the 30B-X cylinder in the DN30-X has the same gross weight as the gross weight of 30B cylinder in the DN30. As a result, the applicant stated and demonstrated that the physical testing results for the DN30 package are representative of the DN30-X package (Calculation Report 0023-BBR-2022-004); therefore, no additional physical testing was performed for the DN30-X package.

2.3.6 Conclusion

The NRC staff reviewed the information provided in the SAR and associated appendices for package testing and model validation. The NRC staff concluded that the LS-DYNA and ANSYS models adequately presented the package geometry and the mass distribution of the components for performing NCT and HAC drop analyses.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.41(a).

2.4 Normal Conditions of Transport

2.4.1 Heat

The applicant performed a thermal analysis of the DN30-X package and presented the evaluation findings in section 2.3, “Thermal Analysis,” of the SAR. The NRC staff’s detailed safety evaluations on the applicant’s thermal analysis are provided in chapter 3.0 of this SER. The applicant stated that the package structural design considered the temperatures predicted by the thermal analysis which considered the ambient temperature range of -40°C to 38°C including insolation. The NRC staff agreed with the applicant and found the statement acceptable.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(1).

2.4.2 Cold

10 CFR 71.71(c)(2) requires that the package is subjected to an ambient temperature of -40°C in still air and shade.

The applicant used a minimum temperature of -40°C to perform drop testing and used material properties at this temperature in the LS-DYNA models. Differential thermal expansion effects for the CCR at the cold conditions were evaluated as discussed in section 2.2.3.2 and section 2.2.5.3 of the SAR. The evaluation results show that the components of the DN30-X package are safe and operational.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(2).

2.4.3 Reduced External Pressure

10 CFR 71.71(c)(3) requires that the package is subjected to a reduced external pressure of 25 kPa.

The 30B-X cylinder is designed for an external and internal maximum allowable working pressure (MAWP) of 172 kPa and 1,380 kPa, respectively. As defined in section 1.2.9 of the SAR, the maximum normal operating pressure (MNOP) of the DN30-X package during transport is 152 kPa. Hence, a reduction to 25 kPa pressure as specified in 10 CFR 71.71(c)(3) will not affect the performance of the 30B-X cylinder.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(3).

2.4.4 Increased External Pressure

10 CFR 71.71(c)(4) requires that the package is subjected to an external pressure of 140 kPa.

The 30B-X cylinder is designed for an external pressure of 172kPa and an internal pressure of 1,380 kPa. As defined in section 1.2.9 of the SAR, the MNOP of the DN30-X package during transport is 152 kPa. Therefore, an external pressure of 140 kPa will not affect the performance of the 30B-X cylinder.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(4).

2.4.5 Vibration and Fatigue

The applicant evaluated fatigue at the lifting points and connections of the package for three different lifting operations and assumed that the package will be in operation for only 100 cycles per shipment and 25 shipments per year during the lifespan of 50 years. Stresses were calculated using the classic hand calculations and a FE analysis using the ANSYS computer program.

The applicant used stresses that are permitted for 150,000 cycles to evaluate fatigue. This is conservative given that the package is not expected to undergo 150,000 cycles. The applicant calculated that the stress amplitude for this design is less than 50% of the available capacity of the material.

The applicant evaluated fatigue of the tie-down weld seams and demonstrated adequate safety margin. The applicant also performed a FE analysis for vibration and the results of the analysis showed that fatigue of the CCS was not of concern. The NRC staff reviewed the evaluations and found them acceptable.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(5).

2.4.6 Water Spray

10 CFR 71.71(c)(6) requires that the package must be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm/h for at least 1 hour.

The water spray test is primarily intended for package relying on materials that absorb water and/or are soften by water material bounded by water soluble glue. The DN30-X is designed such that the DN30-X PSP has no openings, has a gasket, and is shaped to prevent water ingress. The NRC staff reviewed the design of the package and concluded that the water spray test will not impair the package and meets the requirements of 10 CFR 71.71(c)(6).

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(6).

2.4.7 Free Drop

NCT free drops were analyzed for the DN30 package in the operating temperature range of -40°C to +60°C as described in the DN30-X SAR (appendix A of appendix 2.2). The applicant examined the DN30 package for free drops 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 after the free drops under NCT and HAC. The maximum inelastic deformation was very small in the 30B cylinder, which corresponds to a level of damage that is much less than the unacceptable damage examples cited by ANSI N14.1 and USEC-651 that would warrant concern and/or repair. It was observed that there was no damage on the plug and valve. With respect to the closure device, inelastic plastic deformation of the pin did not exceed 6% in any of the LS-DYNA FE analyses, which is well below the 35% rupture strain value of the material.

An additional analysis for the NCT flat drop on the valve side was performed for the DN30-X to demonstrate that stresses near the cylinder valve do not exceed yield.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(7).

2.4.8 Corner Drop

The corner drop is not applicable since the DN30-X package exceeds the minimum weight of 100 kg specified for fiberboard, wood, or fissile material cylindrical packages.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(8).

2.4.9 Compression

For the compression test, the applicant performed a quasi-static FE analysis as discussed in sections 2.2.6.3 and 6.3 of the SAR, appendix 2.2. The results showed that only very small local plastic deformation (dents) below 5% elongation occur at the outer shell that have no impact on any safety feature of the DN30 PSP.

The DN30-X package uses the same PSP, and the 30B-X cylinder has the same outer dimensions as the 30B cylinder, so the compression test analysis is equally valid for the DN30-X package. As a result, the NRC staff determined that the package meets the requirements of 10 CFR 71.71(c)(9) for compression.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(9).

2.4.10 Penetration

10 CFR 71.71(c)(10) requires that impact of a hemispherical end of a vertical steel cylinder of 3.2 cm diameter and 6 kg mass, dropped from a height of 1 m onto the exposed surface of the package, is expected to be most vulnerable to puncture.

The DN30-X package is made of stainless-steel and does not have any valves or opening that would be susceptible to a 6-kg bar impacting it. As demonstrated in section 2.2.6, “Ability of the DN30-X Package to Withstand NCT and HAC” of the SAR, the DN30-X package is designed to withstand the puncture test under HAC, which is much more severe for the DN30-X package weighing about 4100 kg than the penetration test. Therefore, the test as defined in 10 CFR 71.71(c)(10) is covered by the test defined in 10 CFR 71.73(c)(3).

Additionally, the applicant also demonstrated that the penetration test required by 10 CFR 71.71(c)(10) was bounded by the puncture test required by 10 CFR 71.73(c)(3) in the DN30 package (reference 3), which was previously reviewed and accepted by the NRC staff (reference 4).

The NRC staff confirms that the penetration test for the DN30-X package under NCT is covered by the puncture test for the DN30-X package under HAC and agrees that the DN30-X package is not susceptible to the 6-kg bar.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(10).

2.4.11 Conclusion for Normal Conditions of Transport

Based on the reviews of the LS-DYNA and ANSYS FEM models and structural evaluations of the package under NCT, the NRC staff confirmed that the models are representative of the DN30-X package and consistent with the descriptions and results of the analyses provided in the SAR.

In addition, based on the reviews of the hand calculations, drop testing, benchmarking and validation, results of the FE analyses and the applicant’s responses to the NRC staff’s request for additional information for the DN30-X package, the NRC staff concludes that the DN30-X package complies with 10 CFR 71.71 requirements under NTC.

2.5 Hypothetical Accident Conditions

The applicant evaluated the DN30-X package for HAC of free drop, crush, puncture, thermal, and water immersion as required by 10 CFR 71.73.

2.5.1 Free Drop

The applicant used the results of LS-DYNA analyses of free drops for both the DN30 and DN30-X packages to establish the safety of the DN30-X package. The DN30-X uses the same PSP as the DN30 used, and the 30B-X cylinder has the same loaded gross weight as the 30B cylinder had. Therefore, the modeling and physical testing results for the DN30 package are representative of the DN30-X package performance. Comparison of PSP deformations and inelastic strains in the PSP and cylinder for the 10.2 m corner drop and flat drop on the valve end using both the DN30 and DN30-X models showed a difference of less than 5%.

In section 2.2.7.1.1 of the DN30-X SAR, 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 2.2.7.1.1 of the SAR.

The applicant stated the protecting devices for the valve and plug performed their functions and no damage was observed from the plug or valve of the 30B cylinder after the drop sequences.

The inelastic deformation to the 30B cylinder was determined from LS-DYNA. Only very small, isolated spots of inelastic deformations were found on the 30B cylinder after HAC sequences and the maximum inelastic strain of 2.951×10^{-2} was calculated in the 30B cylinder. This corresponds to a maximum deformation that is much less than the unacceptable damage examples cited by ANSI N14.1 and USEC-651 that would warrant concern and/or repair. With respect to the closure device, inelastic plastic deformation of the pin did not exceed 6%, which is well below the 35% rupture value of the material.

The additional DN30-X LS-DYNA models included a center-of-gravity over valve-side corner drop, flat drop onto the valve-side end and a flat drop onto the feet.

These drops evaluated the orientations most damaging to the CCS and 30B-X cylinder including loads on the CCS restraints and CCRs. The maximum inelastic strains in the 30B-X cylinder, CCS restraints, lattice holders, and CCRs are shown in table 1 below.

Table 1. LS-DYNA Model Inelastic Strains for DN30-X Package Analyses

Sequence	30B-X Cylinder	CCS Restraint	Lattice Holder	CCR
Sequence 1	4.00%	0.70%	2.10%	1.00%
Sequence 3	4.0-4.4%	2.60%	2.60%	3.40%
Sequence 9	2.40%	1.00%	3.10%	1.40%

In all cases, the inelastic strains for the components of the DN30-X are well below the uniform strain limit of the materials with sufficient capacity to avoid component rupture, and the resulting cylinder deformations are less than the threshold values cited by ANSI N14.1 and USEC-651 so there are no concerns or repair needed. Additionally, the deformation and relative dislocation of the CCS are within the stated bounding limits (i.e., relative motion of CCRs <5 mm, radial motion of the CCS <3 mm, and axial motion of the CCS <7 mm).

In addition, the strength of the step weld joining the CCR to the lattice holder of the CCS was evaluated for maximum loading under end drop in section 7.2.8 of the SAR, appendix 2.2. The weld evaluated is a 6 x 10 mm weld with 4 mm thickness, but the drawings specify that a 2 x 30 mm weld with 4 mm thickness is used for easier fabrication. The NRC staff determined that the total effective length of the weld is the same for both specifications (360 mm per CCR), so the calculation is sufficiently representative of the weld strength and valid to demonstrate that the design is acceptable.

Based on the review of the modeling and testing, the NRC staff concluded that the DN30-X package meets the requirements of 10 CFR 71.73(c)(1) for free drop.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(1).

2.5.2 Crush

The crush test is not applicable as the DN30-X package weighs more than 500 kg.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(2).

2.5.3 Puncture

The applicant considered the most damaging orientation for key components of the 30B cylinder such as the valve and plug for the DN30 package. The LS-DYNA FE analyses of drop sequences (cumulative damage) that included the puncture bar indicated that there was no damage to the main 30B cylinder components. Since the results of the DN30 package analyses are representative of the DN30-X package, the NRC staff concluded that the DN30-X package meets the requirements of 10 CFR 71.73(c)(3) for puncture.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(3).

2.5.4 Thermal

The applicant performed thermal analysis of the DN30-X package and presented the evaluation findings in section 2.3, “Thermal Analysis,” of the SAR. The NRC staff’s detailed safety evaluations on the applicant’s thermal analysis are provided in chapter 3.0 of this SER. The following evaluation is based on a summary of the applicant’s thermal evaluations provided in sections 2.2.7.3 and 2.3 of the SAR.

The applicant stated that the thermal analysis of the DN30-X package, consisting of the DN30 PSP and the 30B-X cylinder, is based on the thermal analysis of the already licensed DN30 package including the DN30 PSP and the 30B cylinder. This is possible because the standard 30B and 30B-X cylinders are transported in the same DN30 PSP.

The applicant demonstrated that the maximum pressure load on the 30B-X cylinder due to expansion of the intumescent material during the HAC fire was 27 kPa which is well below the external MAWP of 172 kPa. Contact and pressure on the valve or plug of the 30B-X cylinder due to expansion of the intumescent material during the HAC fire was minimal due to the initial clearance gaps in the design. Expansion of the steel and foam components of the PSP during the HAC fire was shown to generate no stresses due to clearance gaps and loss of foam structural integrity.

The internal pressure increase due to melting of the UF_6 during HAC conditions was also calculated. The temperature of the valve, plug, and content exceeds the 64°C triple point of UF_6. The 30B-X. cylinder pressures were calculated and found to be less than the maximum allowable pressure of 2.74 MPa which is twice the MAWP of 1.38 MPa as specified in ANSI N14.1 for the standard 30B cylinder. Acceptable safety margins are shown for the 30B-10 and 30B-20 cylinders in table 2-9 of the SAR.

The 30B-X cylinder has a lower HAC pressure due to increased ullage relative to the standard 30B cylinder which was demonstrated to survive the regulatory HAC fire test and successfully pass leak testing. The NRC staff reviewed the evaluations provided in the DN30-X SAR and concluded that the DN30-X package meets the thermal requirements of 10 CFR 71.73(c)(4).

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(4).

2.5.5 Immersion- Fissile Material

The immersion test for fissile material requirements of 10 CFR 71.73(c)(5) is not applicable since the DN30-X criticality safety analysis assumed water inleakage and optimal moderation.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(5).

2.5.6 Immersion- All Packages

The 30B-X cylinder is designed for an external pressure of 172 kPa that exceeds the expected pressure of 150 kPa at 15 m of water.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(6).

2.5.7 Immersion- Air Transport Accident Conditions for Fissile Material

Air transport of the DN30-X package is not permitted, so the requirements of 10 CFR 71.55(f) do not apply.

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.55(f).

2.5.8 Immersion- Special Requirements for Type B Packages Containing More than 10^5 A_2

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

The NRC staff determined that the application satisfies the regulatory requirements of 10 CFR 71.61.

2.5.9 Conclusion for Hypothetical Accident Conditions

Based on the reviews of the LS-DYNA and ANSYS FEM models and structural analyses of the package under HAC, the NRC staff concludes that the descriptions of the models and results of the structural analyses provided in the SAR are consistent and acceptable. In addition, based on the reviews of the hand calculations, drop testing, benchmarking and validation, results of the FE analyses and the applicant’s responses to the NRC staff’s RAI for the DN30-X package, the NRC staff concludes that the DN30-X package complies with 10 CFR 71.73 requirements under HAC.

2.6 Conclusion for the Structural Safety Evaluation

The NRC staff reviewed and evaluated the applicant’s statements and representations in the application. Based on the review and evaluations, the NRC staff concludes that the Model No. DN30-X transportation package is adequately described, analyzed, and evaluated to demonstrate that its structural capability and integrity meet the regulatory requirements of 10 CFR Part 71.

References

1. 10 CFR Part 71, Packaging and Transportation of Radioactive Material.

2. Orano NCS GmbH (ONCS), Safety Analysis Report DN30-X Package, 0045-BSH-2020-001, Revision 3, 2022.

3. Daher Nuclear Technologies (DNT), Safety Analysis Report DN30 Package, 0023-BSH-2016-002, Revision 1, 2019.

4. U.S. Nuclear Regulatory Commission (NRC), Safety Evaluation Report, Certificate of Compliance No. 9362 for the Model No. DN30 Package, 2019.

5. American National Standard, Uranium Hexafluoride-Packaging for Transport, ANSI N14.1-2019, December 2019.

6. American Society of Mechanical Engineers (ASME) International, Boiler and Pressure Vessel Code, 2017 edition.

7. Forschungskuratorium Maschinebau (FKM), Proof of Strength by Calculation for Machine Parts Made of Steel, Cast Iron and Aluminum Materials, 2012.

8. United States Enrichment Corporation (USEC), The UF_6 Manual – Good Handling Practices for Uranium Hexafluoride, USEC-651, Revision 9, 2006.

2.7 Materials Evaluation

The staff evaluated the materials performance of the Model No. DN30-X package to ensure it meets the requirements of 10 CFR Part 71. The DN30-X package is designed to transport higher enrichment commercial grade uranium hexafluoride (UF_6) in solid form. The DN30-X package is a partially new design, comprised of the previously approved DN30 protective structural packaging (PSP) and the new 30B-10 and 30B-20 cylinders. The DN30-X package is derived from the previously approved 30B cylinder, which was designed in accordance with ANSI N14.1, with the addition of a criticality control system (CCS) to account for the higher enrichments of UF_6. The staff reviewed the aspects of the DN30-X package that were identical to the DN30 package and evaluated the unique elements of the DN30-X package. The staff notes that the DN30-X cylinder design includes these stated deviations from ANSI N14.1, and as such, are not ANSI N14.1 certified cylinders.

2.7.1 Materials of Construction

As described in SAR section 1.4 and the licensed drawings, the DN30 PSP is comprised of an inner and outer shell, two integrated feet, six device closure system, valve protecting device, plug protecting device, and two rotation preventing devices. The inner and outer shells, integrated feet, valve protecting device, plug protecting device, and rotation preventing devices are fabricated from American Society of Mechanical Engineers (ASME) SA-240 stainless steel.

The device closure system is fabricated of ASME SA-479/ASME SA-240 stainless steel. The cavity between the inner and outer shells is filled with a polyisocyanurate rigid (PIR) foam (RTS 120 and RTS 320) with a layer of thermal insulation (MICROTHERM OVERSTITCHED 1000R HY or WDS Multiflex ST 2D50 HY) 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

(Promaseal-PL). The DN30 PSP also has an elastomeric gasket fabricated of ethylene propylene diene terpolymer to prevent ingress of water under routine conditions of transport.

As described in SAR sections 1.4, section 6 of Specification 30B-X, and the licensing drawings, the 30B-X cylinders are comprised of a cylinder shell, backing bars, skirts, valve and plug, and a criticality control system. The cylinder shell, backing bars, and skirts are fabricated from American Society for Testing and Materials (ASTM) A516, grade 65 or 70 steel with couplings fabricated from forged ASTM A105 steel and seal loops fabricated of ASTM A36 steel rod. The cylinder valve body is fabricated of UNS C63600 aluminum bronze and the stem fabricated of ASTM B164 nickel-copper alloy.

As described in SAR sections 1.4, section 6 of Specification 30B-X, and the licensing drawings, the criticality control system is comprised of control rods, three lattice holders, and fourteen longitudinal stiffeners. The control rod lids, lattice holders, and longitudinal stiffeners are fabricated from ASTM A516, grade 65 or 70 steel. The control rod pipes are fabricated from ASTM A106 grade C steel.

Per the above discussion, the staff finds that the applicant’s description of the materials of construction to be acceptable.

2.7.2 Drawings

The applicant provided drawings in appendix 1.4.1A and B of the SAR to incorporate the DN30 PSP, 30B-10 and 30B-20 cylinders, and the criticality control system. The drawings include a parts list that provides the materials of construction and codes/standards for each. The drawings also provide the welding and examination requirements. The staff notes that the level of detail in the new drawings are consistent with the guidance in NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material”.

The staff reviewed the drawing content with respect to the guidance in NUREG/CR-5502, “Engineering Drawings for 10 CFR Part 71 Package Approvals,” and confirmed that the drawings provide an adequate description of the materials, fabrication, and examination requirements, and, therefore, the staff finds them to be acceptable.

2.7.3 Codes and Standards

The DN30 PSP utilizes European standards with applicable ASME equivalents. The applicant also provided the relationship between the International Atomic Energy Agency SSR-6, “Regulations for the Safe Transport of Radioactive Material” regulations used and the requirements of 10 CFR Part 71. The staff reviewed these Codes and Standards and relations to 10 CFR Part 71 and determined that they are acceptable.

As described in SAR section 1.4.1.1, the 30B-10 and 30B-20 cylinders are derived from the standard 30B cylinder as specified in ANSI N14.1, “Uranium Hexafluoride – Packagings for Transport”, with the addition of a criticality control system. The 30B-10 and 30B-20 cylinders adopt the same ANSI N14.1 material standards as the standard 30B cylinder. Except for the poison material, these ANSI N14.1 material standards are also applied to the criticality control system.

The staff notes that the cited standards are consistent with NRC guidance in NUREG-2216, which states that components of packaging important to safety may be specified by industry consensus codes and standards such as American National Standards Institute (ANSI) standards. The staff notes that the DN30-X cylinder design includes deviations from ANSI N14.1, and as such, are not ANSI N14.1 certified cylinders.

Per the above discussion, the staff finds the materials codes and standards to be acceptable.

2.7.4 Weld Design and Inspection

The DN30 PSP utilizes welding/fabrication/examination procedures based on ASME BPVC Section VIII Division 1. Requirements for welders and welding are defined to ensure the structural properties of the DN30 PSP. Therefore, the staff finds the welding criteria to be acceptable.

As described in the appendix 1.4.1A drawings, the new 30B-10 and 30B-20 cylinders welding is in accordance with ANSI N14.1. The weld design will be in accordance with ASME BPVC Section VIII, Division 1, and the welding procedures, processes, and welder qualifications will be in accordance with ASME BPVC Section IX.

The visual examinations of the welds will be performed in accordance with Section UW-51 of ASME BPVC Section VIII, Division 1 and ANSI N14.1. The staff notes that the applicant’s use of the cited ASME codes for the design, fabrication, and examination of the welds is consistent with the guidance in NUREG-2216. Therefore, the staff finds the welding criteria to be acceptable.

2.7.5 Material Properties

SAR appendix 1.4.2 discusses mechanical and thermal properties of materials and materials selection, respectively, of the DN30 PSP and 30B-X cylinders. The staff verified that the mechanical and physical property data for the major structural materials, bolting materials, foam, intumescent material, and thermal insulation were obtained from ASME Code and ASTM Standards, however, some of the values were obtained from manufacturer data verified by acceptance testing data and other acceptable references. The staff reviewed these codes and standards, data, and other technical references to verify material mechanical properties. Likewise, the staff determined that the thermal properties (e.g., thermal conductivity, thermal expansion, etc.) are consistent with those in ASME B&PV codes and technical literature.

The staff reviewed the applicant’s thermal analysis to ensure that these material properties are valid under the expected service conditions. In SAR section 2.3, the applicant evaluated the maximum temperatures of the 30B-X cylinder (body, valve, plug and CCS), cylinder volume (Air, UF_6), and the DN30 PSP (inner and outer shells) under normal and hypothetical accident conditions. The staff reviewed the applicant’s analysis and verified that the component temperatures remain below each of the material’s allowable service temperatures. Therefore, the staff finds the mechanical and thermal properties used in the applicant’s structural and thermal analysis to be acceptable.

2.7.6 Radiation Shielding

As described in SAR section 1.4.4, the DN30-X packaging has no components used primarily for shielding. Some level of shielding is provided via the inner and outer shells of the DN30 PSP. The inner are outer shells have been described in detail above. Therefore, the staff finds the radiation shielding materials to be acceptable.

2.7.7 Criticality Control

As described in SAR sections 1.4.2.1.1 and 2.6.4.3, and the 30B-X Specification, the criticality control rods are fabricated of seamless ASTM A106 steel piping and are filled with boron carbide (B_4C) powder as the neutron absorbing material. The applicant provided a B_4C density value of 1.35 g/cm^3 and credits 88.9% of the B_4C as neutron absorber nuclide.

The staff notes the density value is conservative and bounding for B_4C powder and that the percent credit for boron-based neutron absorbers is appropriate for the control rods filled with B_4C powder. Therefore, the staff finds the criticality control materials to be acceptable.

2.7.8 Corrosion Resistance, Content Reactions, and Radiation Effects

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.

Regarding a potential formation of volatile hydrofluoric acid (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.

As described in SAR section 1.4.8, the DN30 PSP is fabricated of stainless steel and is resistant to corrosion. The outside of the 30B-X cylinders is painted to prevent corrosion. The applicant provided information to show that corrosion of the interior surfaces of the cylinders is negligible. The staff finds the determination acceptable based on the applicant's quantitative discussion 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 by radiolysis and potential gas generation 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.

Therefore, the staff finds the applicant's evaluation of corrosion resistance, potential adverse reactions, and radiation effects to be acceptable.

2.7.9 Protective Coatings

As described in SAR sections 1.4.2.2 and 1.4.8, the inner surfaces of the DN30 PSP are covered by an intumescent material which precludes corrosion of the interior surfaces of the PSP and has an applied coating to facilitate ease of decontamination of the inner shell. Prior to each loading, the intumescent material shall be inspected for damage in accordance with appendix 1.8.2.

As described in SAR sections 1.4.8 and 1.4.9, the 30B-X cylinders are coated with paint to prevent excessive corrosion of all outer surfaces and to facilitate ease of decontamination. As described in SAR section 1.8.2, the cylinders are inspected every 5 years, cleaned, and repainted as required.

Per the above discussion, the staff finds the coating materials and applications to be acceptable.

2.7.10 Package Contents

As described in SAR section 1.3, the content of the package is unirradiated commercial grade uranium, in the form of UF_6, with a ^{235}U mass percentage not to exceed 10% (designated HALEU 10) for the DN30-10 design, and 20% (designated HALEU-20) for the DN30-20 design.

The maximum mass for HALEU 10 is 1460 kg and for HALEU 20 is 1271 kg. The chemical, physical, and isotropic properties are based on the requirements of ASTM C996 and are provided as table 1-1 of the SAR.

The UF_6 is in a solid form during transport. Per the above discussion, the staff finds the description of the package contents to be acceptable.

2.7.11 Bolting Material

The two halves of the DN30 PSP are connected with a mortise-and-tenon system. When the PSP is closed, the two halves of each mortise and tenon are connected via a pin that is secured by a ASME SA-193 stainless steel bolt. The staff reviewed fracture properties and bolt performance 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. Therefore, the staff finds the applicants bolting materials to be acceptable.

2.7.12 Evaluation Findings

The applicant has met the requirements of 10 CFR 71.33. The applicant described the materials used in the transportation package in sufficient detail to support the staff's evaluation. The applicant has met the requirements of 10 CFR 71.31(c). The applicant identified the applicable codes and standards for the design, fabrication, testing, and maintenance of the package and, in the absence of codes and standards, has adequately described controls for material qualification and fabrication.

The applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a). The applicant demonstrated effective materials performance of packaging components under normal conditions of transport and hypothetical accident conditions. The applicant has met the requirements of 10 CFR 71.43(d). The applicant has demonstrated that there will be no significant corrosion, chemical reactions, or radiation effects that could impair the effectiveness of the packaging.

The applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.55(d)(2). The applicant has demonstrated that the package will be designed and constructed such that the analyzed geometric form of its contents will not be substantially altered, no loss or dispersal of the contents, and no substantial reduction in the effectiveness of the packaging under the tests for normal conditions of transport.

The staff concludes that the Orano CoC No. 9388 for the DN30-X packaging adequately considers material properties and material quality controls such that the design is in compliance with 10 CFR Part 71. This finding is reached on the basis of a review that considered the regulation, itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

3.0 THERMAL EVALUATION

The objective of the review was to verify that the thermal performance of the package design has been adequately evaluated for the thermal tests specified under normal conditions of transport and hypothetical accident conditions, and that the package design meets the thermal performance requirements of 10 CFR Part 71.

3.1 Description of the Thermal Design

The DN30-X package consists of a 30B-X cylinder (i.e., 30B-10 cylinder and 30B-20 cylinder) containing UF_6 within the DN30 protective structural packaging (PSP) overpack of the previously certified DN30 package. SAR section 1.4.2.3.1 (document 0045-BSH-2020-001 rev. 3) stated that the 30B-X cylinder is the pressure-containing portion of the package. The overpack of the DN30-X package is the same as the previously certified DN30 PSP and, according to SAR section 1.2.1, existing DN30 PSPs can be used to transport the 30B-10 and 30B-20 cylinders. According to SAR sections 1.3.1.2 and 1.3.2.1, the content of the 30B-10 cylinder and 30B-20 cylinder include commercial natural UF_6 that is enriched up to 10% wt. ^{235}U and 20% wt. ^{235}U, respectively; neither reprocessed UF_6 nor derived enriched UF_6 can be content.

Both the 30B-10 cylinder and 30B-20 cylinder (drawings are listed in SAR section 1.4.1.1) are similar to the previously certified 30B cylinder, which was designed and fabricated per ANSI N14.1 standard “Uranium Hexafluoride – Packaging for Transport”, 2019. SAR section 1.4.2.1 indicated that one significant addition is an interior criticality control system (CCS) built into the 30B-X cylinder. SAR section 1.4.2.1.2 stated that the 30B-X materials (e.g., cylinder, valve, plug) and outer dimensions (as well as the maximum gross weight according to SAR table 1-13) are identical to the standard 30B cylinder that was previously certified and that the 30B-X cylinder can be handled in the same manner as the standard 30B cylinder, although SAR section 1.4.2.1.4 stated that handling of an empty 30B-X cylinder must consider its heavier tare weight due to the presence of the CCS.

SAR table 1-13 listed design aspects associated with the 30B, 30B-10, and 30B-20 cylinders to show that many of the specifications among the cylinders are the same (e.g., diameter, length, nominal wall thickness, maximum gross weight).

According to SAR sections 1.4.2.1 through 1.4.2.1.4 and SAR table 1-13, the 30B-X cylinder is constructed with backing bars and has a 11 mm minimum cylinder wall thickness compared to the 7.94 mm thickness from the previously certified 30B cylinder. These differences result in a larger 30B-20-cylinder tare weight (e.g., 1641 kg for 30B-20) compared to the 30B cylinder tare weight (635 kg). Regarding the differences between the 30B-10 and 30B-20 cylinders, SAR table 1-13 indicated that the 30B-10-cylinder tare weight of 1452 kg is less than the 1641 kg tare weight of the 30B-20 cylinder; the 189 kg greater tare weight of the 30B-20 cylinder is due to the larger number of criticality control rods (CCR).

3.1.1 Thermal design features

As noted in SAR section 1.4.2.3.3 and section 1.4.6, the DN30 PSP provides thermal protection of the 30B-X cylinders, especially during the fire-related hypothetical accident condition. Thermal related design features include the polyisocyanurate rigid foam (PIR) (denoted as RTS 120 and 320 foam) between the overpack's inner and outer shells, MICROTHERM insulation layer between the inner shell and RTS 120 foam, and Promoseal-PL intumescent material attached to the inner shell.

SAR section 1.4.2.2.1 noted that the valve protecting device and plug protecting device are surrounded with intumescent material. Additional specifications associated with these materials were provided in SAR table 1-12.

3.1.2 Codes and standards

As noted in the Certificate of Compliance, the 30B-X cylinder is designed and fabricated in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code and is ASME Code stamped. SAR table 1-9, table 1-10, table 1-11, and table 1-12 provided the material specifications for the 30B-X cylinder, the cylinder's valve and plug, the CCS, and the DN30 PSP, respectively.

3.1.3 Content heat load specification

SAR section 1.3 provided the permissible radionuclides and specification of the Commercial Natural UF_6 contents (neither reprocessed nor derived enriched UF_6 is transported). SAR section 1.3.2.7 and table 1-6 indicated that the decay heat of the content within a 30B-10 cylinder and 30B-20 cylinder is 0.227 W and 0.419 W, respectively, and stated the thermal analyses conservatively assumed a decay heat of 3 W.

3.1.4 Summary tables of temperatures

SAR table 2-11 listed the NCT and HAC admissible temperatures for the DN30 PSP components (e.g., outer shell, inner shell, PIR foam, microporous thermal insulation, and intumescent material) and 30B-X cylinder components (e.g., shell, lattice holder/CCR, neutron absorber, valve, plug, solder).

SAR section 2.3.4.5 and table 2-13 provided the NCT thermal model temperature results of the DN30-X components for an empty 30B-X cylinder, 100% filled 30B-X cylinder, and 50% filled 30B-X cylinder. Results showed components were below the NCT admissible temperatures reported in SAR table 2-11 and indicated an average package temperature of approximately 54 °C.

SAR figure 2-4 presented transient diurnal NCT results over the course of 20 days based on an ambient temperature of 38 °C, showing peak shell temperatures of 63°C and minimum temperatures (i.e., during the 12-hour period without insolation) of approximately 43°C. A 43°C shell temperature without insolation satisfies 10 CFR 71.43(g) requirements for non-exclusive use transport.

Similarly, SAR section 2.3.4.6, SAR table 2-14 (empty 30B-X cylinder), table 2-15 (fully loaded 30B-X cylinder), and table 2-16 (50% filled 30B-X cylinder) provided the HAC thermal model temperature results of the DN30-X, which showed all components were below the HAC admissible temperatures reported in SAR table 2-11. Specifically, the 30B-10 and 30B-20-cylinder valve, plug, mantle, and CCR during the HAC thermal tests were at least 13°C below the 131°C admissible temperature.

3.1.5 Summary tables of pressures in the containment system

SAR section 1.4.2.3.1 stated the 30B-X cylinder is the containment boundary and that the DN30 PSP is not a pressure retaining component. Regarding NCT, SAR section 1.2.9 specified a maximum normal operating pressure (MNOP) of 152 kPa, which is the pressure of UF_6 at the triple point temperature of 64.1°C. However, according to SAR section 2.3.4.5, NCT thermal analyses have shown 30B-X cylinder temperatures of approximately 53°C. Correspondingly, SAR section 1.3.2.8 and section 1.7.2.1 stated the UF_6 is transported in a solid form such that the UF_6 vapor pressure is below atmospheric; this indicates the above-mentioned MNOP value is larger relative to typical transport pressures within the cylinder.

Regarding HAC, table 3-3 of appendix 2.3 (document 0045-BSH-2020-001-Apppendix-2.3 Rev. 0) provided the pressures of 50% and 100% fill ratios at the 131°C admissible temperature.

Pressures within the 30B-10 cylinder with 50% and 100% fill ratios were calculated as 0.93 MPa and 1.16 MPa, respectively. Similarly, pressures within the 30B-20 cylinder with 50% and 100% fill ratios were calculated as 0.93 MPa and 1.1 MPa, respectively. Based on the information provided in SAR section 2.2.2.1.1, these pressures are less than the 1.38 MPa (gauge) internal maximum allowable working pressure at 121 °C and less than the 2.76 MPa (gauge) 30B-X cylinder hydraulic strength test pressure specified in ANSI N14.1.

3.2 Material Properties and Component Specification

3.2.1 Material thermal properties

SAR table 1-1 and section 5.3.4.1 of appendix 2.3 provided physical properties of the UF_6 content. Figure 5-1 of appendix 2.3 provided the geometry of the DN30-X thermal model, including its components and materials and section 5.3.4 of appendix 2.3 provided a discussion of the thermal properties used in the thermal model. This included the thermal conductivity, density, and specific heat (heat capacity) of carbon steel, stainless steel, RTS 120 foam, RTS 320 foam, intumescent material, microporous thermal insulation, and air.

Appendix 2.3 discussed that some material properties would be affected by the HAC fire (e.g., RTS foam, intumescent material), and therefore, material property values during the HAC fire were determined by using information from prototype testing (described in section 5.4 of appendix 2.3), including thermocouple data, to adjust property data so that numerical results of prototype thermal model analyses would better match prototype measurements. Emissivity properties were provided in appendix 2.3 section 5.3.9.2, section 5.3.10.1, and table 5-19.

Additional material discussion is presented in the SER Materials evaluation.

3.2.2 Specifications of components

SAR section 1.4.1.1 indicated that the 30B-X cylinder's materials are the same as the previously certified 30B cylinder. The material specifications of the 30B-X cylinder, valve, plug, CCS, and DN30 PSP were listed in SAR table 1-9 through table 1-12; specifically, the details and standards associated with the thermal plugs, thermal insulation, intumescent material, and foam were provided in SAR table 12.

Additional details of the 30B-X specification were found in document 0045-SPZ-2021-001-Rev1 "Specification 30B-X". This document, SAR section 1.7, and SAR section 1.8 described quality assurance and general cylinder requirements related to cylinder design, fabrication, in-service inspections and tests, maintenance, and repair. In addition, the document described specific cylinder requirements, including materials, fabrication, radiography, valve, plug, external heat treatment, and certification. Details of the CCS boron carbide were also provided in the document.

3.2.3 Thermal design limits of package materials and components

SAR section 2.3.2 stated that the maximum allowable working temperature of the 30B-X cylinders was 131°C. Likewise, SAR table 2-11 listed the maximum allowable temperatures of the DN30 PSP components. As noted below, the package temperatures were below allowable limits for NCT and HAC. In addition, SAR section 1.2.8 stated that the lowest transport temperature allowed for the DN30-X package was -40°C.

3.3 General Considerations for Thermal Evaluations

SAR section 1.4.2.1.1 indicated the CCRs that end in front of the 30B-X cylinder valve and plug are shortened by 40 mm to prevent interference with filling and emptying of the cylinder and to ensure there is no impact of the CCS on the valve and or plug during NCT or HAC. SAR section 1.7.2.1 noted that the 30B-X cylinder is weighed before filling to confirm the net weight of the heels is below the allowable quantity of 11.3 kg and weighed after filling to ensure the cylinder fill limit is not exceeded. "Facility operations with the 30B-X Cylinder" (document 0045-BSH-2020-001-Appendix 1.7.3, Rev. 1) indicated that proper temperature control and weighing of the cylinder during filling and emptying are means to ensure there are no impacts by the CCS that would impair the 30B-X cylinder to meet the shipment requirements of the packaging and content.

Finally, SAR section 1.7 and section 1.8 discussed 30B-X operations and inspections; staff notes that these procedures were also associated with the previously certified DN30 package, which were performed in accordance with ANSI N14.1 and at least as described in USEC 651 "The UF_6 Manual – Good Handling Practices for Uranium Hexafluoride", Rev. 9, 2006.

SAR sections 1.4.2.1.3 and 1.4.2.1.4 describe the change in ullage of a filled 30B-X cylinder due to the presence of the CCS volume and indicated the mass of UF_6 in a 30B-X cylinder is reduced to account for the CCS volume. Therefore, the ullage of a filled 30B-X cylinder is greater than a standard 30B cylinder, thereby having a larger allowance if content expansion were to occur.

Specifically, 30B cylinder UF_6 mass is 2277 kg which results in an ullage of 5% at 121°C. The 30B-10-cylinder UF_6 mass is 1460 kg which results in an ullage of 17.6% at 121°C and the 30B-20-cylinder UF_6 mass is 1271 kg which results in an ullage of 20.8% at 121°C. The effect on pressure due to the greater ullage of the 30B-X cylinders was shown in appendix 2.3 table 3-3, which showed a high total 30B-10-cylinder pressure of 1.16 MPa, which is lower than the 30B cylinder's pressure of 2.51 MPa.

SAR section 1.3.1.3 stated that safety, health, and criticality requirements for HALEU 10 and HALEU 20 content were identical to the requirements provided in section 4 of ASTM C996 "Standard Specification for Uranium Hexafluoride enriched to less than 5 wt. % ^{235}U". These requirements included maximum total absolute vapor pressure of the content in order to limit hydrogen fluoride, air, and other volatile components that may cause overpressure when 30B-X cylinders are heated.

Another requirement was limiting total hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon content to 0.01 mol% of the UF_6 in order to prevent vigorous reactions with UF_6 when heated. Staff notes that these requirements, which are listed in the CoC, were also associated with the previously certified 30B cylinder.

3.3.1 Evaluation by analyses

SAR section 2.3.4.1 stated that the DN30-X package thermal analyses were performed using the ANSYS Workbench 2022 R2 finite element software, which can model conduction, convection, and radiation heat transfer modes.

Section 5.3 of appendix 2.3 indicated that the NCT and HAC thermal model was an axisymmetric two-dimensional geometry of the DN30 PSP and the 30B-X cylinder (based on the structural analysis of the 30B-10 and 30B-20-cylinder hybrid model) and, according to SAR section 2.3.3 was validated and benchmarked using two thermal tests with DN30 prototypes. Materials associated with the thermal model included stainless steel, microporous insulation, RTS 120 foam, RTS 320 foam, intumescent material, carbon steel, carbon steel with boron carbide, air, and UF_6; thermal properties were presented in section 5.3.4 of appendix 2.3, as noted earlier.

Appendix 2.3 section 5.3 and section 5.4 indicated that thermal contact resistances and conductance between components were considered in the model by considering the benchmarking of the thermal calculation model with the prototype fire tests. Likewise, heat transfer in the cavities between the skirts of the 30B-X cylinder at the valve and plug ends and the intumescent material were modeled using radiation, conduction, and convection. According to section 5.3.2, the CCS was also modeled, such that CCS weight, radial positions of the CCRs, and the lateral positions of the lattice holders were made equivalent to the structural analyses.

Section 5.3.7 of appendix 2.3 indicated the maximum decay heat of 3 W was applied as a volumetric heat source considering the minimum internal volume of the 30B-20 cylinder. Modeling of heat generation due to foam pyrolysis was described in section 5.3.7.2 of appendix 2.3 and considered the foam's incineration rate and heat generation rate, which was a function of the foam's enthalpy of reaction.

Benchmark analysis of prototype testing and measured weight loss of foam samples at elevated temperatures were used to gain insight into the foam's pyrolysis behavior for determining incineration and heat generation rate parameters. According to the response of staff's request for additional information, the foam's heat generation was non-negligible, being orders of magnitude greater than the decay heat, although much less than the thermal input from the fire over its 30-minute duration.

Regarding NCT modeling, appendix 2.3 section 5.3.5 indicated the ambient temperature and initial temperature of the transient NCT calculations was 38°C. Appendix 2.3 section 5.3.9.2 indicated that convective heat transfer from the DN30-X package during NCT and after the fire was modeled using a specified Nusselt correlation.

Likewise, appendix 2.3 section 5.3.8 and table 5-15 showed that exterior horizontal surface and vertical surface boundary surfaces included 400 W/m^2 and 200 W/m^2 insolation fluxes, respectively, over a 12-hour period; zero insolation was applied for the subsequent 12-hour period.

According to SAR table 2-13 and figure 2-4, transient NCT results over the course of 20 days showed peak shell temperatures of 63°C and minimum transient temperatures of approximately 43°C (i.e., during the 12-hour period without insolation). As noted earlier, the 43°C shell temperature without insolation satisfies 10 CFR 71.43(g) for non-exclusive use transport.

Regarding HAC modeling, SAR figure 2-5 showed the initial temperature for the transient HAC calculation was a uniformly applied 63°C, which is conservative compared to the NCT calculation's 53°C package interior component temperature presented in SAR table 2-13. Ambient temperature prior to the fire and during the post-fire cooldown period was 38°C.

According to appendix 2.3 section 5.3.9.2, the surface absorptivity was set as 0.8 and the flame emissivity was set as 0.9, which are consistent with 10 CFR 71.73. Convective heat transfer from the DN30-X package during the 30-minute HAC fire was modeled using a specified Nusselt correlation. Heat transfer in the air gaps caused by the cavities between the plug and valve ends of the 30B-X cylinder and the DN30 PSP intumescent material considered radiation, convection, and conduction heat transfer.

Appendix 2.3 indicated that a specified Nusselt correlation was used to determine convection heat transfer within gaps and a conductance within the gap was applied based on the benchmark calculations. In addition, emissivity values associated with the gaps were provided in table 5-19.

According to appendix 2.3 section 5.3.3, the ANSYS thermal model's mesh consisted of approximately 54,000 nodes and 42,000 elements. Section 5.7.3 presented results of mesh size and time step size sensitivity analyses, which showed less than 1°C maximum temperature changes in package components.

3.3.2 Evaluation by tests

Section 5.4 of appendix 2.3 described the fire HAC benchmarking and validation of the finite element model with two DN30 prototype fire tests of the DN30 PSP and an empty (i.e., low thermal mass) 30B cylinder. These analyses are relevant because, as noted earlier, the DN30 PSP overpack and 30B cylinders are similar to the DN30-X package.

SAR section 5.4 and appendix 2.3 indicated that a focus of the benchmarking and validation was associated with determining appropriate numerical modeling of the damaged package due to the impact of the HAC tests, including the fire test (e.g., modeling damaged RTS 120 foam, RTS 320 foam, and intumescent material).

For example, appendix 2.3 section 5.3.7.1 discussed the use of the benchmark tests as well as tests showing the weight loss of RTS foam samples as a function of temperature. The benchmarking and validation with the prototype tests allowed for changing properties of the package foam and the heat generation due to foam incineration to be included in the HAC thermal analysis.

Appendix 2.3 section 5.4.1.4 noted that the benchmark and validation model at fire conditions did not include decay heat from UF_6 content because the 30B cylinder was empty during the prototype test program; staff notes this would not have a significant impact on results considering the actual content decay heat is less than 0.5 W according to SAR table 1-6.

Appendix 2.3 table 5-21 and table 5-22 indicated that ambient temperatures during the prototype fires were between approximately 900°C and 1000°C, which are greater than the 800°C engulfing fire condition described in 10 CFR 71.73. Results that compare package component temperatures between transient numerical analyses and prototype fire HAC test measurements (presented in appendix 2.3 section 5.4) showed relatively good agreement throughout the test period.

According to section 5.4.4, the agreement indicated that the material properties and foam pyrolysis parameters were well suited for subsequent DN30-X package thermal analyses under regulatory conditions. This indicates that the assumptions of the parameters used in the modeling of the HAC fire may be considered acceptable to the extent their use resulted in the simplified 2D model reasonably matching the results of prototype tests; the use of the parameter values for other designs or aspects were not considered or demonstrated.

3.3.3 Effects of uncertainties and conservatisms

According to appendix 2.3 section 5.7, a number of numerical sensitivity thermal HAC analyses were performed to gain insight into the effect of certain material properties and modeling approaches, including potential package conditions after undergoing HAC tests. These analyses focused on an empty 30B-X cylinder because analyses had shown this would result in higher package temperatures.

One sensitivity analysis focused on the effect of there being contact between the CCS and the ellipsoidal head of the 30B-X cylinder rather than a gap. Results showed that valve and plug temperatures were reduced by approximately 20°C when the CCS was in contact with the cylinder. Another sensitivity analysis modeled the impact of contact between the 30B-X cylinder and the DN30 PSP. The results of this analysis showed valve and plug temperatures increased by approximately 2°C due to the cylinder being in contact with the DN30 PSP.

A second set of sensitivity analyses focused on the impact of reduced microporous insulation thickness from manufacturing tolerances and damages due to drop tests as well as loss of portions of microporous insulation and foam after being dropped onto a bar prior to the HAC thermal test.

Appendix 2.3 stated that the loss of insulation and foam from impacting the bar was added damage to the HAC thermal model, considering that the baseline calculations already took into account the damage from the 9 m drop and bar impact tests via the benchmarking of the foam material properties from the damaged prototype tests.

Results from a small reduction in microporous insulation thickness due to manufacturing tolerances showed valve and plug temperatures increased by approximately 1°C. Larger reductions in microporous insulation thickness (conservatively applied uniformly throughout the model) due to potential damages from the free drop HAC tests likewise resulted in higher valve and plug temperatures during HAC fire conditions. For example, reducing the thickness by half increased temperatures by approximately 5°C.

The postulated damage from the drop onto the bar was modeled by forming an annular gap (matching the area of the test bar) around the circumference of the cylinder such that there was loss of microporous insulation at the valve and plug. The sensitivity analysis considered an area loss of insulation that was one, two, and four times the area of the bar diameter. Results showed plug temperatures increasing by approximately 8°C for the postulated loss of insulation area that was four times the bar diameter.

Finally, a sensitivity analysis considered a loss of microporous insulation and foam, in which a circumferential gap was formed at the package ends between the inner and outer shell of the DN30 PSP and the valve and plug locations; there were no penetrations of the package shells. The gap area sizes investigated were one and two times the area of the bar diameter. Results showed that valve and plug temperatures increased by approximately 10°C for the case of the gap being twice the bar area.

A third set of sensitivity analyses focused on the impact of foam material properties and the parameters that modeled the foam pyrolysis process. Results showed that varying thermal conductivity and heat capacity of the RTS 120 and RTS 320 foam could increase valve and plug temperatures by approximately 3°C. Likewise, varying the factors used to calculate the heat generation of the foam pyrolysis could increase valve and plug temperatures by approximately 1°C.

Results from the above-mentioned sensitivity analyses showed that 30B-X cylinder and DN30 PSP temperatures remained below allowable values.

3.4 Evaluation of Accessible Surface Temperature

As noted earlier when describing the ANSYS thermal model, appendix 2.3 section 5.3.5 indicated the ambient temperature and initial temperature of the transient diurnal NCT calculations were 38°C and, according to appendix 2.3 section 5.3.9.2, a convection heat transfer during NCT was applied to the DN30-X package surface.

Likewise, appendix 2.3 section 5.3.8 and table 5-15 showed that exterior horizontal surface and vertical surface boundary surfaces included 400 W/m^2 and 200 W/m^2 insolation fluxes, respectively, over a 12-hour period; zero insolation was applied for the subsequent 12-hour period.

According to SAR table 2-13 and figure 2-4, transient NCT results over the course of 20 days showed peak shell temperatures of 63°C and minimum transient temperatures (i.e., during the 12-hour period without insolation) of approximately 43°C; this temperature without insolation satisfies 10 CFR 71.43(g) for non-exclusive use transport.

3.5 Thermal Evaluation under Normal Conditions of Transport

The effects of NCT structural tests on the package were described in SAR sections 2.2.6.1, 2.2.6.2, 2.2.6.3, 2.2.6.4, 2.2.6.5, and 2.2.7, which indicated the NCT tests would have no adverse effect on the DN30-X package in meeting regulations.

3.5.1 Heat and cold

The package ANSYS thermal model was used to analyze hot (38°C) normal transport conditions based on transient diurnal boundary conditions described in SAR section 2.3.4.4.4 and table 2-12. Results in SAR table 2-13 indicated that package temperatures were below allowable values presented in SAR section 2.3.2.

For example, cylinder valve, plug, mantle, and CCS were below the 64°C allowable temperature with margins of at least 13°C. SAR table 2-13 also showed that temperatures of an empty 30B-X cylinder (which has greater thermal mass than a 30B cylinder, per SAR table 1-13) were less than temperatures of an empty 30B cylinder.

SAR figure 2-4 showed exterior shell surface temperatures were approximately 43°C for the condition of no insolation, thus satisfying the nonexclusive-use temperature requirement described in 10 CFR 71.43(g).

Regarding cold conditions, SAR section 1.2.8 indicated that the DN30-X package has a low allowable temperature of -40°C.

3.5.2 Maximum Normal Operating Pressure

SAR section 1.2.9 stated that the maximum normal operating pressure of the DN30-X package is 152 kPa, which is the pressure at the triple point of UF_6; it was also noted that the 30B-X cylinder has a maximum allowable working pressure of 1.38 MPa.

As noted earlier, SAR section 1.3.2.8 and section 1.7.2.1 indicated that the UF_6 content is in a solid phase with a vapor pressure below atmospheric when the package is transported; thus, there would be lower pressures than the UF_6 triple point value.

3.6 Thermal Evaluation under Hypothetical Accident Conditions

3.6.1 Initial conditions

SAR figure 2-5 indicated that the initial temperature of the entire 30B-X package was set at 63°C. This is a conservative assumption because, as noted in SAR table 2-13, only the DN30 PSP outer shell had a 63°C maximum temperature based on hot NCT (38°C) thermal calculations.

3.6.2 Fire test conditions

As noted earlier, appendix 2.3 section 5.3 stated that the fire temperature was 800°C for a 30-minute duration and the ambient conditions considered insolation at 38°C during the 6.5-hour cooldown phase. Appendix 2.3 section 5.3.9.2 stated that the surface absorptivity was set as 0.8 and the flame emissivity was set as 0.9. Emissivity values associated with gaps in the models were provided in table 5-19.

Convective heat transfer from the DN30-X package during the 30-minute HAC fire was modeled using a specified Nusselt correlation. Heat transfer in the air gaps caused by the cavities between the plug and valve ends of the 30B-X cylinder and the DN30 PSP intumescent material considered radiation, convection, and conduction heat transfer. A specified Nusselt correlation was used to determine the convection heat transfer within the gap and a conductance within the gap was applied based on benchmark calculations.

3.6.3 Maximum temperatures and pressures

SAR section 2.3.4.6 provided temperatures of the cylinder's valve, plug, and mantle and the DN30 PSP's inner shell and outer shell when modeling the empty, 50% filled, and 100% filled 30B-X cylinder. Specifically, SAR figure 2-5 and table 2-14 as well as figure 2-8 and table 2-15 provided the temperature profile of these components during the seven-hour transient for empty and 100% filled conditions. Figure 2-11 provided the cylinder valve's transient temperature profile of a 30B-X cylinder that was empty, 50% filled, and 100% filled.

The results showed that the empty 30B-X cylinder temperatures were approximately 8°C higher than the full cylinder with its greater thermal mass. For example, according to table 2-16, the maximum valve temperature for an empty cylinder was 118°C compared to the 110°C valve temperature of the full cylinder; temperatures for both fill ratios were below the 131°C allowable temperature.

As noted earlier, a sensitivity analysis was also performed to show that if there was direct contact between the CCRs and the ellipsoidal heads, rather than a gap, temperatures would be further reduced. The results indicate the impact of differences between the simplified hybrid cylinder numerical model from a non-hybrid model would not be significant. In addition, the above result showing lower temperatures for cylinders with higher thermal mass was also noted in SAR table 2-13 that showed the 30B-X cylinder, which has greater thermal mass than a 30B cylinder, had lower temperatures compared to the previously certified 30B cylinder.

SAR table 2-15 showed no significant differences in temperature associated with the DN30 PSP overpack components (e.g., inner shell, outer shell) whether the 30B-X cylinder was empty or filled. According to figure 2-5, the DN30-X outer shell reached approximately 790°C, which was below the 900°C admissible temperature reported in SAR table 2-11.

Appendix 2.3 presented the pressure calculations of the 30B-10 and 30B-20 cylinders at the maximum admissible cylinder temperature of 131°C. The results were reported in table 3-3 and showed that the maximum pressure at 100% fill ratio for the 30B-10 cylinder and 30B-20 cylinder was 1.16 MPa and 1.1 MPa, respectively, which are less than the 1.38 MPa maximum allowable working pressure. These pressures were also less than the 30B cylinder's 100% fill ratio pressure of 2.51 MPa; this shows the greater ullage in the 30B-X cylinders result in lower cylinder pressures. In addition, it is noted that pressures in the 30B-X cylinders would tend to be lower than the values described above because cylinder temperatures reported in SAR table 2-14 and table 2-15 are less than 131°C.

Finally, with regards to hypothetical accident conditions, SAR section 2.4.3 stated that prototype test results showed that the leakage rate after HAC tests were below $1\text{x}10^{-6}$ Pa m^3/sec, which is orders of magnitude less than the $1\text{x}10^{-4}$ Pa m^3/sec SLR leakage acceptance criterion.

3.7 Evaluation Findings

The staff has reviewed the package description and evaluation and concludes that they satisfy the thermal requirements of 10 CFR Part 71. The staff has reviewed the material properties and component specifications used in the thermal evaluation and concludes that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71. The staff has reviewed the methods used in the thermal evaluation and concludes that they are described in sufficient detail to permit an independent review of the package thermal design.

The staff has reviewed the accessible surface temperatures of the package as it will be prepared for shipment and concludes that they satisfy 10 CFR 71.43(g) for packages transported by non-exclusive use vehicle. The staff has reviewed the package design, construction, and preparation for shipment and concludes that the package material and component temperatures will not extend beyond the specified allowable limits during normal conditions of transport consistent with the tests specified in 10 CFR 71.71.

The staff has reviewed the package design, construction, and preparation for shipment and concludes that the package material and component temperatures will not exceed the specified allowable short-term limits during hypothetical accident conditions consistent with the tests specified in 10 CFR 71.73.

Based on review of the statements and representations in the application, the NRC 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 containment design of the Model No. DN30-X package conveying a 30B-X cylinder (i.e., 30B-10 cylinder and 30B-20 cylinder) 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.

The DN30-X package is a Type A(F) package for the transport of 30B-10 and 30B-20 cylinders containing commercial grade UF_6 with enrichments of 10% wt. and 20% wt. commercial grade ^{235}U of natural isotopic composition, respectively, within a DN30 protective structural packaging (PSP); neither reprocessed UF_6 nor derived enriched UF_6 can be content. As noted in SAR section 1.2.1 (document 0045-BSH-2020-001 Rev. 3), a 30B-X cylinder is transported using the same DN30 PSP that was previously certified for the DN30 package. The DN30-X 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 is a condition of the CoC.

The containment evaluation focused on the 30B-10 and 30B-20 cylinders, which are the containment systems of the DN30-X package. According to SAR section 1.4.2.3.1, the DN30 PSP is not considered part of the containment system.

4.1 Description of Containment System

The packaging consists of the DN30 PSP overpack that holds either a 30B-10 cylinder or 30B-20 cylinder during transport and provides structural and thermal protection of the cylinder during normal and accident conditions.

SAR section 1.4.2.3 indicated the DN30 PSP includes a valve protecting device and a plug protecting device that act as barriers to prevent contact of the 30B-X cylinder's valve and plug with other parts of the DN30 PSP during accident conditions. The flange that connects the top half and bottom half of the DN30 PSP includes an elastomeric gasket to prevent water in-leakage. Six mortise-and-tenon closure devices ensure the 30B-X cylinder remains within the DN30 PSP, and therefore, the 30B-X cylinder cannot be accessed during transport. Likewise, SAR section 1.7.4.2 indicated that shipping seals are installed after the mortise-and-tenon devices are secured with bolts.

According to SAR section 1.4.2.1, the package's containment boundary is either the 30B-10 cylinder or 30B-20 cylinder and that these cylinders are similar to the previously certified standard 30B cylinder, which was designed and fabricated per ANSI N14.1. According to the CoC, the UF_6 cylinder is designed and fabricated in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code and is code stamped.

The 30B-X cylinder containment boundary consists of the 30B-X shell, heads, and their welds, the valve body and stem including the threaded connection between the valve and the 30B-X cylinder, and the plug including the threaded connection between the plug and the 30B-X cylinder. The valve and plug include a tin-lead alloy solder used during cylinder fabrication according to SAR table 1-10 and, as noted above, the valve and plug are protected from damage during NCT and HAC by a valve protection device and plug protection device.

The 30B-X materials are the same as the previously certified 30B cylinder materials, according to SAR section 1.4.1.1.1. The containment boundary has no pressure relief device and there is no feature that allows continuous venting during transport, thus satisfying 10 CFR 71.43(e).

The drawings associated with the 30B-X cylinder were listed in SAR section 1.4.1 and 1.4.1.1.

4.2 General Considerations for Containment Evaluations

According to SAR sections 1.4.2.1 through 1.4.2.1.4 and SAR table 1-13, the 30B-X cylinder includes the interior criticality control system (CCS) that is built into the 30B-X cylinder. In addition, SAR section 1.4.2.1.2 also stated that CCS restraints are welded to the straight portion of each cylinder head, thereby also acting as backing bars for the cylinder's circumferential head welds. The minimum wall thickness of the 30B-X cylinder is increased to 11 mm from the 7.94 mm value specified in the previously certified 30B cylinder.

Likewise, SAR section 1.4.2.1.4 indicated the nominal tare weight (empty cylinder) of the 30B-X cylinder is greater than the previously certified 30B cylinder due to the mass of the CCS, however, table 1-13 indicated that the 30B-X cylinders have greater ullage than the 30B cylinder, which would result in greater margin for pressure buildup caused by melted UF_6.

SAR section 1.3.2.11, table 1-7, table 1-8, and figure 1-2 provided calculation results that showed the total activity associated with filled 30B-10 and 30B-20 cylinders. The calculation assumed ten 3-month cycles (filled and transported to destination and then returned to enrichment facility with heels and with no washing taking place) for five years followed by 10-year storage of a filled cylinder. The analysis conservatively assumed that the decay products associated with the prior cycle's heel quantity (11.3 kg) and its corresponding decay products were added in each cycle (i.e., decay products associated with multiples of 11.3 kg heel quantity).

The results in SAR table 1-8 indicated that the maximum activity in the 30B-10 cylinder was 0.301 A2 and the maximum activity in the 30B-20 cylinder was 0.557 A_2, thus supporting the Type A package designation. As noted in SAR section 1.3.2.11, this is a conservative calculation because the quantity of heels for each shipment is limited to 11.3 kg (i.e., some decay products associated with previous heel quantities would be removed with the heel quantity).

According to SAR section 1.3, the UF_6 would have no more than 10% wt. and 20% wt. enrichment of commercial grade U-235 with natural isotopic composition (i.e., content is not from reprocessing and not from down-blended) within the 30B-10 and 30B-20 cylinder, respectively. Specifically, SAR table 1-2 and table 1-3 provided the permissible radionuclide contents and isotopic limits of the HALEU 10 and HALEU 20 within the 30B-X cylinder; plutonium is not a permissible content.

SAR table 1-4 indicated that the 30B-10 can include a maximum of 1460 kg of UF_6 and 11.3 kg of heel quantities and the 30B-20 can include a maximum of 1271 kg of UF_6 and 11.3 kg of heel quantities. According to SAR section 1.3.2.4, the content is neither special form nor low dispersible and is shipped in solid form.

SAR section 1.3.2.1 noted that the current cleaning processes for standard 30B cylinders generally achieve heel quantities below 2 kg. The application ratioed the internal free surfaces associated with the 30B-X cylinder and the 30B cylinder and multiplied by the 2 kg heel quantity in order to account for the effect of a greater quantity of internal free surface inside the 30B-X cylinder that the CCS (e.g., free surface of the criticality control rods (CCR), lattice holder, longitudinal stiffener) can have on emptying the UF_6. Multiplying the area ratio and the 2 kg heel quantity from the standard 30B cylinder resulted in a 9.7 kg mass, which is less than the allowable 11.3 kg heel quantity.

As noted in SAR section 1.7.2.1, the 30B-X cylinder is weighed before filling to confirm the net weight of the heels is below the allowable quantity of 11.3 kg and weighed after filling to ensure the cylinder fill limit is not exceeded.

SAR section 1.3.1.3 noted that safety, health, and criticality requirements for HALEU 10 and HALEU 20 are identical to the requirements in section 4 of ASTM C996 "Standard specification for uranium hexafluoride enriched to less than 5% ^{235}U" for enriched commercial grade UF6 with a maximal enrichment of 5 wt.-% ^{235}U, including limiting total absolute vapor pressure to prevent overpressure in the cylinders and limiting total hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon content (not exceed 0.01% mol % of the UF_6) to prevent vigorous reaction as well as criticality specifications and other relevant content properties and limits; requirements listed in section 4 of ASTM C996 are also noted in the CoC.

SAR section 1.3.2.11 indicated that a cylinder is recertified after five years, which requires the cylinder to be emptied and washed. In addition, SAR section 1.7 and section 1.8 discussed 30B-X operations and inspections; staff notes that these procedures were also associated with the previously certified DN30 package that had procedures performed in accordance with ANSI N14.1 and at least as described in USEC 651 “The UF_6 Manual – Good Handling Practices for Uranium Hexafluoride”, Rev. 9, 2006.

Additional information on facility operations was presented in “Facility operations with the 30B-X Cylinder” (document 0045-BSH-2020-001-Appendix 1.7.3 Rev. 1), which indicated that proper temperature control and weighing of the cylinder during filling and emptying are means to ensure there are no impacts by the CCS that would impair meeting the shipment requirements of the packaging and content.

SAR section 1.7.2.1 discussed the vacuum leakage test and air pressure drop leakage rate test of the valve seat after filling and prior to shipment; staff notes that these tests were also associated with the previously certified 30B cylinder that had tests in accordance with ANSI N14.1 and ANSI N14.5. The acceptance criteria included a standardized leakage rate less than 1E-4 Pa m^3/sec. In addition, ANSI N14.1 describes details of the fabrication, maintenance, and periodic leakage rate testing of UF_6 cylinders of 30B size. Examples of these containment boundary tests were noted in SAR section 1.8.2 and include a hydraulic strength test and a 100-psig pneumatic leakage rate test when a cylinder plug or valve has been changed.

Further details about operations and inspections related to the containment boundary were provided in appendix 1.7.1 (Use and Handling of the DN30-X package, Handling Instruction 0045-HA-2021-001), appendix 1.7.3 (Facility Operations with the 30B-X Cylinder, 0045-BSH-2020-001-Appendix -1.7.3, Rev. 1), and appendix 1.8.1 (Periodic Inspections of the 30B-X Cylinder, Test Instruction 0045-PA-2021-001-Rev 0).

SAR section 1.6 indicated there would be no significant flammable gas generation or galvanic, chemical reactions associated with the 30B-X cylinders, which have the same materials of construction as the previously certified 30B UF_6 cylinders, thus satisfying 10 CFR 71.43(d).

Likewise, SAR section 1.4.11.1 stated that the shock absorbing material is a closed cell structure that is free of acids and halogens and the thermal protection materials are inorganic materials that are free of acids and halogens; SAR sections 1.4.6 and 1.4.10 listed the shock absorbing and thermal protection components, including the RTS 120 and RTS 320 foam and microporous thermal insulation.

SAR section 1.2.9 indicated that the maximum normal operating pressure for the DN30-X package, when transporting either the 30B-10 cylinder or 30B-20 cylinder, is 152 kPa (0.152 MPa), which is based on the triple point of UF_6. SAR section 2.2.2.1.1 stated that the 30B-X cylinder is designed for an internal maximum allowable working pressure (MAWP) of 1.38 MPa (gauge) at 121°C, as specified in ANSI N14.1.

Likewise, section 2.2.2.1.1 stated that the cylinder can withstand an external maximum allowable working pressure of 172 kPa (gauge). Finally, SAR section 2.3.2 indicated that the admissible pressure under HAC (which is based on the hydraulic test pressure of twice the maximum allowable working pressure) is 2.74 MPa for a 131°C temperature, which is less than the approximately 1 MPa pressure within the 30B-X cylinders at 131°C reported in appendix 2.3 (document 0045-BSH-2020-001-Apppendix-2.3 Rev. 0).

4.3 Containment Evaluation under Normal Conditions of Transport

As noted above, the MNOP is 0.152 MPa, which is less than the 1.38 MPa internal maximum allowable working pressure (MAWP) at a 121°C. Likewise, according to SAR section 2.1.1.1.3, the DN30-X has a NCT and HAC operating temperature range of -40°C to 60°C.
SAR table 1.6.1.4 and SAR section 1.7.1 (including Appendix 1.9.2A “Manufacturing Specification 30B-X cylinder” and Appendix 1.9.2B “Manufacturing Specification DN30 PSP”) discuss the manufacturing specifications, testing requirements, and controls before first use of the 30B-X cylinder and DN30 PSP to ensure there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the DN30-X package.

SAR section 2.1.1.1.3, section 2.2.6, and section 2.2.7 indicated that the DN30-X package can withstand NCT tests (water spray, free drop test, compression, penetration, reduced and increased external pressure) for an operating temperature range of -40°C to 60°C.

Additional considerations and analyses described in SAR section 2.1.1.1.3, section 2.2.5.2, and section 2.2.7 confirm that the package meets NCT requirements, including no dispersal of radioactive contents during NCT, no contact between the valve or the plug with the DN30-X overpack (thus the containment function is maintained, according to SAR section 1.5.3.1), and no damage to the containment system when undergoing the NCT 1.2 m free drop test, HAC 9 m free drop test, and HAC puncture test. Further discussion about the NCT and HAC tests is presented in the SER Structural Evaluation.

SAR sections 1.2.3 and 1.3.2.5 indicated that the content in the Type A(F) package has less than an A_2 activity. The applicant stated in SAR section 1.2.10 that the maximal standardized helium leakage rate of the 30B-X cylinder would be $1x10^{-4}$ 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 SAR section 2.4; this acceptance criteria also applies to testing of a filled cylinder according to SAR section 1.7.2.1. This SLR was less than the leakage rate calculations (carried out in accordance with ANSI N14.5) for the 30B-10 cylinder or 30B-20 cylinder in either the UF_6 filled condition or the heeled condition, according to SAR table 2-18.

As discussed in the detailed calculation procedure found in appendix 2.4 (document 0045-BSH-2020-001-Appendix 2.4- Rev 0), the calculation to determine the $1x10^{-4}$ Pa.m^3/s standard leakage rate (SLR) was conservatively based on an A_2 value. In addition, SAR section 2.4.3 indicated the performance of the package design by noting leakage rate tests of prototype packages performed after HAC tests showed measured leakage rates of 10^{-6} Pa-m^3/sec, which is much less than the $1x10^{-4}$ Pa.m^3/s standard leakage rate.

Details of maintenance (e.g., valve and plug replacements) and periodic leakage rate tests are similar to those for the previously certified 30B cylinders, where were described in ANSI N14.1. According to SAR section 1.7.2, leakage rate testing is in accordance with ANSI N14.5-2014.

Staff finds that performing the leakage rate test prior to shipment and the condition of the 30B-X cylinder after undergoing NCT tests provide reasonable assurance that the containment boundary will meet 10 CFR 71.43(g) requirements of there being no dispersal of contents.

4.4 Containment Evaluation Under Hypothetical Accident Conditions

SAR section 1.2.3 indicated that the content has less than an A_2 activity, and therefore the DN30-X is classified as a Type A(F) package. The application addressed the impact of the hypothetical accident conditions on the package, as noted below.

SAR section 2.1.1.1.3.1 and section 2.2.7.1.3 indicated that the interaction between the DN30 PSP and 30B-X cylinder is similar to the interaction between the previously certified DN30 PSP and 30B cylinder. Specifically, SAR section 2.2.7 discussed a comparison of the DN30-X package and the DN30 package with section 2.2.7.4 concluding that experimental drop tests performed for the DN-30 package as well as the new analyses to address the aspects of the 30B-X cylinder and its interaction with the DN30 PSP (including the thermal test under HAC) show that there is no physical contact between the valve of the 30B-X cylinder and any other package component, no physical contact between the plug of the 30B-X cylinder and any other package component, and no rupture of the 30B-X cylinder containment system under HAC.

SAR section 2.2.7.4 also noted that helium leakage rate tests after the experimental DN30 drop tests showed leakage rates less than 10^{-6} Pa m^3/sec. This value is below the $1x10^{-4}$ Pa m^3/sec SLR acceptance criterion for the helium leak acceptance test that each 30B-X cylinder undergoes, as described in SAR section 2.4.3. Likewise, with regards to thermal hypothetical accident conditions, SAR appendix 2.3 (document 0045-BSH-SAR-2020-001-Appendix-2.3 Rev. 0) section 4.6 stated that the leakage rates, after thermal tests were performed on two prototype packages that underwent hypothetical accident condition fire test, were $6.63x10^{-9}$ Pa m^3/sec (prototype with microporous insulation) and $3.4x10^{-5}$ m^3/sec (prototype without microporous insulation), which are less than the $1x10^{-4}$ Pa m^3/sec SLR leakage acceptance criterion.

4.5 Evaluation Findings

The staff has reviewed the applicant’s description and evaluation of the containment system and concludes that the application identifies established codes and standards for the containment system, the package includes a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package, and the valve and plug is protected against unauthorized operation.

The staff has reviewed the applicant’s evaluation of the containment system under normal conditions of transport and concludes that the package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71, “Normal Conditions of Transport”, the package satisfies the containment requirements and specifications of 10 CFR 71.43(f) and 10 CFR 71.51(a) for normal conditions of transport with no dependence on filters or a mechanical cooling system.

Based on review of the statements and representations in the application, the NRC staff concludes that the package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71.

5.0 SHIELDING EVALUATION

The staff reviewed the application to use the Orano NCS DN30-X package to transport

UF_6 enriched up to 20% by weight (wt.%) as a Type AF package and verified that the package criticality safety design has been described and evaluated under NCT as required in 10 CFR Part 71. This review also considered whether the package is consistent with the acceptance criteria in section 5 (Shielding Evaluation) of NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material."

5.1 Description of shielding design

5.1.1 Shielding design features

Staff reviewed both the general information chapter in the DN30-X application and the information presented in the shielding evaluation chapter. The package consists of a 30B-X UF_6 cylinder contained within a DN30-X protective structural package (PSP) to protect the cylinder during shipment.

The DN30-X package is a simple steel clamshell design with polyisocyanurate rigid (PIR) foam and a 10-millimeter (mm) layer of thermal insulation between the inner shell and the PIR. The 30B-X UF_6 cylinder is similar to an ANSI N14.1 certified 30B UF_6 cylinder, except that it contains a criticality control system (CCS) inside the cylinder. The CCS consists of an arrangement of criticality control rods (CCRs), which are steel tubes filled with boron carbide (B_4C), in three lattice holders to hold them in place, as shown in figures 1-3 and 1-4 of the SAR.

There are two variations of 30B-X cylinders: the 30B-10, which can contain UF_6 enriched up to 10 wt.%, and the 30B-20, which can contain UF_6 enriched up to 20 wt.%. Each DN30-X package can accommodate one filled 30B-X UF_6 cylinder per package.

The DN30-X packaging has no components primarily intended for shielding. The shielding analysis considers the presence of the 30B-X cylinder shell as well as the inner and outer shells of the DN30 PSP and includes the presence of the CCS inside the cylinder.

5.1.2 Codes and standards

The applicable regulations considered in the review of the shielding evaluation portion of this application include the external dose rate requirements in 10 CFR Part 71, specifically the external radiation standards for all packages in 10 CFR 71.47. The staff also used the review guidance contained in NUREG-2216.

5.1.3 Summary tables of maximum external radiation levels

The applicant provided summary tables of maximum external radiation levels under routine conditions of transport in section 2.5 of the SAR. Tables 2-19 and 2-20 provide the maximum external radiation levels at 1 meter (m) from the package surface and at the package surface, respectively, for UF_6 enriched up to 10 wt.%, UF_6 enriched up to 20 wt.%, heels of UF_6 enriched up to 10 wt.%, and heels of UF_6 enriched up to 20 wt.%.

In all cases, the dose rates are less than the requirements in 10 CFR 71.47. The maximum external dose rates at the package surface and 1m from the package surface are for heels of UF_6 enriched up to 20 wt.%.

These dose rates were 476 micro-Sieverts per hour (μSv/h) (compared to the regulatory limit of 2,000 μSv/h in 10 CFR 71.47(a)) at the package surface, and 56 μSv/h (compared to the regulatory limit of 100 μSv/h in 10 CFR 71.47(a)) at 1m from the package surface.

5.2 Radioactive materials and source terms

The contents of the DN30-X package consist of either a 30B-10 or 30B-20 cylinder, with UF_6 enriched up to 10 or 20 wt.%, respectively, meeting the limits for uranium isotopes and technetium-99 (^{99}Tc) impurity shown in table 1-2 of the SAR. The maximum masses of UF_6, as shown in table 1-4 of the SAR, are 1,460 kilograms (kg) in the 30B-10 cylinder, and 1,271 kg in the 30B-20 cylinder. The maximum mass of heels in any empty cylinder is 11.3 kg.

Full 30B-10 or 30B-20 cylinders, or empty cylinders with heel quantities, will contain some radioactive progeny from the uranium decay chain, as shown in table 3-1 of Appendix 2.5 of the SAR. For the shielding analysis of full cylinders, the applicant conservatively assumed that the radioactive uranium decay progeny build-up over a period of 10 years (UF_6 cylinders are typically cleaned and washed after five years).

For the analysis of heeled cylinders, the applicant conservatively assumes that all non-uranium nuclides built up from when the cylinder was full remain in the cylinder with the heel contents, and only decay for one day. The staff finds that the applicant has conservatively estimated the radioactive contents that can be present in the DN30-X package under all conditions.

5.2.1 Source term calculation methods

The applicant used the ORIGEN point isotopic depletion and decay code, with the 27n-19g ENDF/B-VII neutron and gamma cross section library, to determine the gamma and neutron source terms for the DN30-X package containing a full or heeled 30B-10 or 30B-20 UF_6 cylinder.

The staff finds that the applicant's source term calculation method is acceptable, as ORIGEN is a standard code used throughout the nuclear industry for determining radioactive material neutron and gamma source terms.

5.2.2 Gamma sources

The gamma source term resulting from the applicant's ORIGEN calculation is shown in table 3-2 of appendix 2.5 of the SAR, for both 10 wt.% and 20 wt.% UF_6 contents. The gamma source term for heel quantities of UF_6 is shown in table 3-4 of appendix 2.5 of the SAR. The staff finds that the applicant's estimated gamma source term is consistent with that expected for higher enriched UF_6 contents and is acceptable.

5.2.3 Neutron sources

The neutron source term resulting from the applicant's ORIGEN calculation is shown in table 3-3 of appendix 2.5 of the SAR, for both 10 wt.% and 20 wt.% UF_6 contents. The neutron source term for heel quantities of UF_6 is very low, as neutrons come primarily from the uranium contents, which are minimal in the heels. The applicant conservatively overestimates the dose from the neutron source of the heels by multiplying the gamma source intensity by 1.05. The staff finds that the dose from applicant's estimated neutron source term correction is conservative compared to that expected for higher enriched UF_6 contents and is acceptable.

5.3 Shielding model and model specifications

5.3.1 Configuration of source and shielding

The applicant modeled the DN-30X package using several conservative simplifications, which cause the package external dose rate to be overestimated. These simplifications include modeling the hemispherical heads of the 30B-X cylinder as flat heads; ignoring the cylinder skirts, valve, and plug; modeling the minimum wall thickness of the 30B-X cylinder (1.1 centimeter (cm)); modeling the filled cylinder as completely full of UF_6, with no ullage; modeling the heeled cylinder with the maximum heels quantity allowed (11.3 kg); and modeling the PSP impact and thermal protecting foam between the inner and outer shells with a reduced density.

Additionally, under NCT, the applicant modeled the PSP with a reduced outer diameter and reduced thickness of impact and thermal protection. For empty cylinders with heels, the applicant modeled the heels in three different orientations: 1) a thin layer of UF_6 contents adhering to the inner side of the cylinder wall, 2) a pool of UF_6 contents collected at the bottom of the horizontal cylinder, and 3) a pool of UF_6 contents collected on one end of the cylinder.

This modeling approach minimizes attenuation from package structural and shielding components and maximizes radioactive contents. The staff finds that the applicant's shielding model is appropriate for determining compliance with 10 CFR Part 71 external dose rate requirements and is conservative.

5.3.2 Material properties

The chemical, physical, and isotopic properties of the UF_6 contents are described in section 1.3.1.4 of the SAR. Material properties of the 30B-X cylinder, CCS, and DN30-X PSP are given in tables 1-9, 1-11, and 1-12 of the SAR, respectively. The primary components of the packaging relied on for shielding are the steel shells of the 30B-X cylinder and the PSP, and the polyisocyanurate (PIR) foam between the inner and outer PSP shells. There is also significant self-shielding of the UF_6 contents in the filled cylinder model.

The staff finds that the material properties used in the applicant's shielding model are consistent with those for the contents and packaging material of the DN30-X package.

5.4 Shielding evaluation

5.4.1 Methods

The applicant performed full three-dimensional shielding analysis of the DN30X package with filled and heeled 30B-10 and 30B-20 UF_6 cylinders. The applicant used the MAVRIC sequence of the SCALE 6.2.3 and 6.2.4 code system, with the Monaco three-dimensional Monte Carlo particle transport code and the 27n-19g ENDF/B-VII neutron and gamma cross section library, to determine surface and 1 m external dose rates for the package. The staff finds that the computer code and cross section data used by the applicant to determine external package dose rates is acceptable.

5.4.2 Fluence-rate-to-radiation-level conversion factors

The applicant used fluence-to-radiation-level conversion factors from the International Commission on Radiation Units and Measurements (ICRU) publication 57 to obtain dose rates in Sv/h from gamma fluences calculated by MAVRIC. This differs from the American National Standards Institute/American Nuclear Society (ANSI/ANS) 6.1.1-1977 Standard fluence-to-radiation-level conversion factors recommended in NUREG-2216.

Since the package is a Type AF package, where dose rates are expected to be low, and the applicant calculated dose rates that are significantly below the regulatory dose rate limits in all cases, the staff finds the applicant's use of alternative fluence-to-radiation-level conversion factors acceptable.

5.4.3 External radiation levels

The applicant calculated maximum external radiation levels under routine conditions of transport as shown in tables 2-19 and 2-20 for 1 m from the package surface and at the package surface, respectively, for UF_6 enriched up to 10 wt.%, UF_6 enriched up to 20 wt.%, heels of UF_6 enriched up to 10 wt.%, and heels of UF_6 enriched up to 20 wt.%. In all cases, the dose rates are less than the requirements in 10 CFR 71.47.

The maximum external dose rates at the package surface and 1m from the package surface are for heels of UF_6 enriched up to 20 wt.%. These dose rates were 476 micro-Sieverts per hour (μSv/h) (compared to the regulatory limit of 2,000 μSv/h in 10 CFR 71.47(a)) at the package surface, and 56 μSv/h (compared to the regulatory limit of 100 μSv/h in 10 CFR 71.47(a)) at 1m from the package surface.

For NCT, with a reduced package outer diameter, the applicant calculated an increase in package surface dose rate of 11.4%, demonstrating that there is "no significant increase in external surface radiation levels" per the requirements of 10 CFR 71.43(f). The staff finds that the increase in external radiation level under NCT calculated by the applicant is conservative and meets the requirements of 10 CFR 71.43(f).

5.5 Evaluation Findings

The staff concludes that the shielding design of the DN30-X when used as described in the application is in compliance with 10 CFR Part 71 and that the applicable design and acceptance criteria have been satisfied. The staff has reasonable assurance that the DN30-X design will provide safe transportation of enriched UF_6. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes, and standards, the applicant's analysis, and responses to requests for additional information, and acceptable engineering practices.

Based on its review of the statements and representations provided in the application, the staff has reasonable assurance that the shielding evaluation is consistent with the appropriate codes and standards for shielding analyses and NRC guidance. Therefore, the staff finds that the package design and contents satisfy the dose rate limits in 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The staff reviewed the application to use the Orano NCS DN30-X package to transport UF_6 enriched up to 20 wt.% 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 Evaluation) of NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material."

6.1 Description of criticality design

6.1.1 Packaging design features

Staff reviewed both the general information chapter in the DN30-X application and the information presented in the criticality safety chapter of the SAR. The package consists of a 30B-X UF_6 cylinder contained within a DN30 protective structural package (PSP) to protect the cylinder during shipment. The DN30-X 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. The 30B-X UF_6 cylinder is similar to an ANSI N14.1 certified 30B UF_6 cylinder, except that it contains a criticality control system (CCS) inside the cylinder. The CCS consists of an arrangement of criticality control rods (CCRs), which are steel tubes filled with boron carbide (B_4C), in three lattice holders to hold them in place, as shown in figures 1-3 and 1-4 of the SAR. There are two variations of 30B-X cylinders: the 30B-10, which can contain UF_6 enriched up to 10 wt.%, and the 30B-20, which can contain UF_6 enriched up to 20 wt.%. Each DN30 package can accommodate one filled 30B UF_6 cylinder per package.

6.1.2 Codes and standards

The applicable regulations considered in the review of the criticality safety portion of this application include the fissile material requirements in 10 CFR Part 71, specifically the general requirements for fissile material packages in 10 CFR 71.55, and the standards for arrays of fissile material packages in 10 CFR 71.59. The staff also used the review guidance contained in NUREG-2216.

6.1.3 Summary table of criticality evaluations

The applicant provided a summary of criticality evaluations and resulting k_{eff} values in section 2.6.6 of the SAR for single packages, and in section 2.6.7 of the SAR for arrays of packages. The maximum k_{eff} reported is for the single package containing a 30B-20 cylinder with optimum internal moderation by water, and with the UF_6 contents conservatively assumed to convert entirely to UO_2F_2. This k_{eff} is 0.9341, including all biases and uncertainties, which is less than the applicant’s reported Upper Subcritical Limit (USL) of 0.9419.

6.1.4 Criticality safety index (CSI)

The applicant demonstrated that an infinite array of DN30-X packages, containing either a 30B-10 or 30B-20 UF_6 cylinder, will remain subcritical under NCT and HAC. The corresponding CSI for the DN30-X package is therefore 0.0.

6.2 Contents

The allowable fissile material contents to be transported in the DN30-X are commercial enriched natural uranium in the form of UF_6 enriched to a maximum of 20 wt.% ^{235}U, as specified in section 1.3.1 of the SAR. Reprocessed or down-blended UF_6 is not an authorized content. The

DN30-X package may contain one 30B-10 cylinder with UF_6 enriched up to 10 wt.%, or one 30B-20 cylinder with UF_6 enriched up to 20 wt.%. The isotopic composition of the package UF_6 contents is shown in table 1-2 of the SAR.

The applicant conservatively ignores all isotopes except ^{235}U and ^{238}U, as the other isotopes act as non-fissile neutron absorbers. The maximum masses of UF_6 for the 30B-10 and 30B-20 cylinders, for both filled cylinders and empty cylinders with heel quantities, are shown in table 1-4 of the SAR. The package may also contain UF_6 impurities consisting of free hydrofluoric acid (HF) and hydrogenated uranium compounds (HUR).

The applicant's criticality analysis considers the presence of these impurities, in cases where they may affect package reactivity. The staff finds that the applicant has appropriately identified all fissile and neutron moderating contents important to the criticality analysis of the DN30-X package.

6.3 General considerations for criticality evaluations

6.3.1 Model configuration

The applicant modeled single DN30-X packages and arrays of packages, each containing either one 30B-10 cylinder with UF_6 enriched up to 10 wt.%, or one 30B-20 cylinder with UF_6 enriched up to 20 wt.%, under NCT and HAC. The applicant modeled the density of UF_6 at the maximum theoretical density of 5.5 grams per cubic centimeter (g/cm^3), except where the density is assumed to vary to find the maximum system k_{eff}. The axial and radial dimensions of the 30B-X cylinder are not affected by NCT and HAC, as shown in section 2.2 of the SAR, and the applicant therefore modeled the cylinder with the as-built dimensions.

The applicant neglected the cylinder valve, plug, and name plate in all models. For all calculations, the applicant also conservatively neglected the CCS lattice holders. The applicant also considered water penetration into the foam of the PSP, where it is modeled.

For evaluations of single package criticality safety under NCT and HAC, the applicant conservatively neglected the presence of the DN30-X PSP and modeled the 30B-10 or 30B-20 cylinder surrounded by a 30 cm water reflector. The applicant considered optimal internal moderation of the cylinder by water by varying the volume fractions of UF_6 and water within the cylinder. This evaluation conservatively considered UF_6 quantities both higher and lower than the mass limits for the 30B-10 and 30B-20 cylinders, 1,460 kg and 1,271 kg, respectively. For the single package, the HF and HUR impurities are neglected by the applicant, as optimum moderation by water results in a higher system k_{eff} value.

Under HAC, the applicant considers potential deformations of the CCS resulting from the 9m drop test, including axial and radial shifting of the CCRs. Additionally, the applicant evaluates conservative, but unlikely scenarios where: 1) UF_6 forms a heterogeneous lattice with water, or 2) UF_6 completely converts to UO_2F_2 in a mixture with water.

For arrays of packages, the applicant modeled infinite arrays under HAC, as this configuration bounds the package configuration under NCT. As the structural analysis in section 2.2 of the SAR demonstrates that the 30B-X cylinder valve and plug are not contacted during the HAC tests required by 10 CFR 71.73 (as discussed in section 2.0 of this report), the applicant did not model water in-leakage.

The applicant considered the presence of 0.5 wt.% HF mixed within UF_6 and 11.3 kg of HUR impurities. The HUR impurities are conservatively modeled as a sphere of UO_2F_2 and H_2O where the location within the cylinder varied to find the position that results in highest system k_{eff}. The remainder of the cylinder is modeled full of UF_6 with 0.5 wt.% HF, conservatively overestimating the amount of UF_6 present in the package. To model damage to the DN30-X PSP, the applicant modeled the thickness of the PSP reduced to 10 cm in the radial direction, and 8 cm in the axial direction.

Additionally, the applicant evaluated a conservative configuration where the inner and outer shells of the PSP are compacted around the cylinder, ignoring the presence and spacing of the PIR foam in between the shells.

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-X package.

6.3.2 Material properties

Staff verified that the applicant identified all relevant material properties of the DN30-X package and the intended fissile material to be transported. For UF_6, the applicant considered pure UF_6 at an enrichment of either 10 wt.% ^{235}U for the 30B-10 cylinder or 20 wt.% for the 30B-20 cylinder and used the maximum theoretical density of UF_6 of 5.5 g/cm^3. The applicant also analyzed UF_6 with a purity of 99.5 wt.% UF_6 with 0.5 wt.% HF, as well as any additional impurities in the form of HUR, at the same density range.

Additional material properties important to the criticality evaluation are for the steel shell, heads, and skirts of the 30B-X cylinder, stainless steel shells of the PSP, PIR foam material between the PSP shells, steel tubes of the CCRs, and boron carbide (B_4C) powder in each CCR. The applicant modeled the B_4C neutron absorber material in each CCR at 1.2 g/cm^3, which is less than 90% of the minimum specified density of 1.35 g/cm^3. This is consistent with the recommendation in NUREG-2216 for credit for solid homogeneous boron-based neutron absorbers, which the staff finds acceptable.

Specifications for the UF_6 contents are detailed by the applicant in section 1.3.1 of the SAR. The material properties of the 30B-X cylinder, CCS, and DN30-X PSP are detailed by the applicant in tables 1-9, 1-11, and 1-12 of the SAR, respectively. The staff finds the applicant's stated material properties to be conservative and acceptable for the purposes of the criticality safety evaluation of the DN30-X package.

6.3.3 Analysis methods and nuclear data

For all criticality calculations, the applicant used the CSAS6 sequence of the SCALE 6.1.2 computer code system, with the KENO VI three-dimensional neutron transport code and the 238-group ENDF/B-VII.0 cross section library.

The applicant also used the TSUNAMI sequence of the SCALE 6.1.2 computer code system to determine similarity coefficients (c_k) of selected critical benchmarks to establish system similarity and applicability for using experiments to validate the criticality analysis of the DN30-X package.

The staff used the CSAS6 sequence of the SCALE 6.2.4 computer code system, with the KENO VI three-dimensional neutron transport code and the continuous energy ENDF/B-VII.0 cross section library to perform selected confirmatory criticality analyses of the DN30-X package.

The staff also performed confirmatory c_k determinations of the applicant's selected critical benchmark experiments using the TSUNAMI sequence of the SCALE 6.2.4 computer code system.

6.3.4 Demonstration of maximum reactivity

For single packages under HAC, using the modeling configuration described in section 6.3.1 of this report, the applicant varied the volume fraction of UF_6 and water in the 30B-10 and 30B-20 cylinders to find the optimum moderation leading to the highest system k_{eff} with nominal cylinder conditions (i.e., no CCS deformation due to HAC). The results of this analysis are shown in table 18 of appendix 2.6 of the SAR.

Using the optimum moderation condition for each cylinder type, the applicant then evaluated the effects of manufacturing tolerances by varying the cylinder diameter and length, wall thickness, inner and outer CCR wall diameter, and CCR length. The results of these analyses are summarized in section 8.2 of appendix 2.6 of the SAR.

Using the most reactive model considering optimum moderation and manufacturing tolerances, the applicant performed a series of analyses to evaluate the effects of potential CCS deformation under HAC. The applicant considered both radial and circumferential relocation of CCRs, as well as axial and radial shifting of the entire CCS within the cylinder.

In all cases, the applicant considered shifts that are significantly larger than the maximum deformation determined in the structural analysis of section 2.2 of the SAR. The results of these analyses are summarized in section 8.3 of appendix 2.6 of the SAR.

The applicant also performed evaluations of heterogeneous lattices of UF_6 and water inside each cylinder type, and for a configuration where all of the UF_6 in the cylinder converts to UO_2F_2 and is optimally moderated by water. Staff finds that both conditions are unlikely, as UF_6 exposed to water is not expected to form a regular lattice, nor would the UF_6 be expected to completely convert to UO_2F_2. However, both configurations are conservative compared to the more realistic evaluated configurations.

The results of the applicant's lattice analyses are shown in section 8.4 of appendix 2.6 of the SAR, and the results of the applicant's UO_2F_2 analysis are shown in section 8.5 of appendix 2.6 of the SAR. The system k_{eff} for the UO_2F_2 analysis is the highest for both the 30B-10 and 30B-20 cylinders and is therefore used for comparison to the applicant's calculated USL from the benchmarking analysis.

For infinite arrays of DN30-X packages under HAC, using the modeling configuration described in section 6.3.1 of this report, the applicant modeled the UF_6 with HF impurities distributed throughout the contents, and the 11.3 kg HUR in a concentrated sphere within the 30B-10 and

30B-20 cylinder. The HUR is modeled as UO_2F_2 and H_2O to represent the appropriate H/X ratio within the residue.

The applicant performed calculations to determine optimum location of the HUR sphere, and to determine the optimum amount of water outside the cylinder. The results of these calculations are summarized in sections 9.1 and 9.2 of appendix 2.6 of the SAR.

The applicant performed an additional infinite array analysis where the inner and outer shells of the package PSP are collapsed onto the outside of the 30B-10 and 30B-20 cylinder, with the PIR foam insulation material entirely removed and package to package spacing correspondingly reduced. The staff finds this condition unlikely, as the structural analysis in section 2.2 of the SAR demonstrates much less compaction of the PSP under HAC. However, this configuration is conservative than the more realistic evaluated configuration.

The results of this calculation are summarized in section 9.2.2 of appendix 2.6 of the SAR. The system k_{eff} for the compacted PSP analysis is the highest for both the 30B-10 and 30B-20 cylinders in the DN30-X package and is therefore used for comparison to the applicant's calculated USL from the benchmarking analysis.

The staff reviewed the configurations modeled by the applicant for the single package and array analyses. The staff agrees that the applicant has identified the most reactive credible condition of the single package and arrays of packages, consistent with the condition of the package under NCT and HAC, and the chemical and physical form of the fissile and moderating contents.

6.3.5 Confirmatory analyses

The staff's confirmatory analyses consisted of selected models of single packages and arrays of packages containing either a 30B-10 or 30B-20 cylinder. Using modeling assumptions similar to the applicant's, the staff's independent evaluation resulted in k_{eff} values that were similar to, or bounded by, the applicant's results.

6.4 Single package evaluation

6.4.1 Configuration

The applicant evaluated the DN30-X single package configuration for all probable design variations, including variation of the outer dimensions and wall thickness of the 30B-X cylinder, optimum internal moderation due to water in-leakage, variation of the dimensions of the CCRs within the CCS, and potential relocation of the CCRs and CCS due to HAC.

6.4.2 Results

The most reactive single package model, described in section 2.6 of the SAR and summarized in section 6.3.4 of this report, resulted in a maximum system k_{eff} plus three times the calculation Monte Carlo uncertainty (3σ) of 0.9321 for the DN30-X with the 30B-10 cylinder, and 0.9341 for the DN30-X with the 30B-20 cylinder. This is less than the applicant's calculated single package USL from the benchmarking analysis of 0.9419.

Based on the analysis performed by the applicant demonstrating the reactivity of the various single package conditions, staff found that the single package is subcritical, and meets the single package criticality safety requirements of 10 CFR 71.55.

6.5 Evaluations of package arrays

6.5.1 Package arrays under normal conditions of transport

The applicant stated that the evaluation of package arrays under NCT is bounded by the consideration of infinite arrays of packages under HAC. The staff finds that the requirements of 10 CFR 71.59 for package arrays under NCT are met by the applicant's consideration of infinite arrays under HAC.

6.5.2 Package arrays under hypothetical accident conditions

The applicant evaluated the DN30-X infinite array configuration for all probable design variations, including variation of the outer dimensions and wall thickness of the 30B-X cylinder, optimum configuration of potential UF_6 impurities, optimum external moderation by water, variation of the dimensions of the CCRs within the CCS, potential relocation of the CCRs and CCS due to HAC, and potential collapsing of the package PSP greater than that demonstrated in the HAC tests.

6.5.3 Package arrays results and CSI

The most reactive package array model, described in section 2.6 of the SAR and summarized in section 6.3.4 of this report, resulted in a maximum system k_{eff} plus 3σ of 0.7654 for the DN30-X with the 30B-10 cylinder, and 0.9039 for the DN30-X with the 30B-20 cylinder. This is less than the applicant's calculated package array USL from the benchmarking analysis of 0.9263.

The applicant demonstrated that an infinite array of DN30-X packages, containing either a 30B-10 or 30B-20 UF_6 cylinder, will remain subcritical under NCT and HAC. The corresponding CSI for the DN30-X package is therefore 0.0.

Based on the analysis performed by the applicant demonstrating the reactivity of the various package array conditions, staff found that arrays of DN30-X packages are subcritical and meet the package array criticality safety requirements of 10 CFR 71.59.

6.6 Benchmark evaluations

6.6.1 Experiments and applicability

The applicant provided a benchmarking analysis to validate SCALE 6.1.2 and the 238-group ENDF/B-VII cross section data used to establish criticality safety of the DN30-X. This analysis considered the characteristics of the DN30-X system, for both single packages and package arrays, in selecting applicable experiments. The applicant selected evaluated criticality safety benchmark experiments from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) that were similar to the DN30-X system.

The applicant used the TSUNAMI module of the SCALE 6.1.2 code system and the 44-group covariance data to perform sensitivity and uncertainty analyses of selected critical benchmark experiments and determine a c_k value for each experiment relative to the DN30-X single package model. The applicant considered experiments with a c_k value greater than 0.8 to be applicable to the application model, which is consistent with guidance from Oak Ridge National Laboratory (ORNL), the developer of SCALE and TSUNAMI.

This approach yielded 76 benchmark experiments which were applicable to the DN30-X single package model. Details of the experimental series selected to benchmark the DN30-X single package criticality calculations, including TSUNAMI analysis results and direct perturbation sensitivity analyses to confirm the results, are provided by the applicant in section 5.2.1 of appendix 2.6 of the SAR.

The applicant used the k_{eff} values resulting from the selected benchmark experiments to determine code bias and bias uncertainty using the single sided lower tolerance limit approach, according to the recommendations of NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages."

For validation of the package array calculations of the DN30-X, the applicant selected critical experiments using a traditional approach of comparing experiment parameters to package system parameters and selecting experiments with similar characteristics. Since the DN30-X array model is not well moderated, and contains materials not typically present in critical experiments, the applicant used the energy of the average neutron lethargy causing fission (EALF) measure as the primary experiment selection criteria.

The applicant selected experiments with a range of EALF from 10 to 100,000 electron volts (eV) to bound the EALF of the most reactive array model, 402 eV for the DN30-10 and 1929 eV for the DN30-20. This selection process resulted in 31 applicable experiments, and the applicant used the k_{eff} values from these experiments to determine code bias and bias uncertainty using the single sided lower tolerance limit approach, according to the recommendations of NUREG/CR-6361.

Although this validation approach is less rigorous than that used by the applicant for the single package analysis validation, the staff finds it acceptable, since the calculated USL is conservatively low, and the maximum calculated k_{eff} for the array analysis is considerably lower than the USL (>2% in k_{eff}).

The staff performed confirmatory benchmarking calculations for the DN30-X package. The staff verified that the critical experiments selected by the applicant were applicable to the single package model. The staff used the TSUNAMI sequence of the SCALE 6.2.4 code package, with the ENDF/B-VII.0 252-group cross section library and 252 group covariance data, to independently select experiments from the ORNL Verified, Archived Library of Inputs and Data (VALID) experiment library with high c_k values compared to the package with the requested contents.

The staff then used the USLSTATS code within the SCALE 6.2.4 package to independently determine a USL for the package evaluated with the SCALE 6.2.4 code and 252-group ENDF/B-VII.0 cross section library. The staff calculated a USL for the DN30-10 and DN30-20 configurations that was similar to the applicant's calculated USLs, based on a c_k trending analysis. Although this analysis was performed using a different version of the SCALE code and different set of critical experiments, this indicates that the USL calculated by the applicant is appropriate for the criticality analysis of the DN30-X system.

6.6.2 Bias determination

The applicant used the k_{eff} results from the selected benchmark experiments, determined to be applicable to both the single package and package array models, to determine code bias and bias uncertainty using the USLSTATS module of the SCALE code package.

Using the single sided lower tolerance limit approach according to the recommendations of NUREG/CR-6361, the applicant determined USLs of 0.9419 for the single package model and 0.9263 for the package array model.

The staff reviewed the applicant's benchmarking analysis in section 2.6 of the SAR and in section 5 of appendix 2.6 of the SAR. The staff agrees that the single package and package array USLs are determined in a conservative manner, consistent with the recommendations of NUREG/CR-6361 and are therefore acceptable.

6.7 Evaluation Findings

The staff evaluated the assumptions used by the applicant and the modeling methodology used in determining the subcriticality of the DN30-X package loaded with a 30B-10 or 30B-20 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-X package, 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 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 package operating procedures are contained in appendix 1.7.1 of the application "Use and handling of the DN30-X package", Handling Instruction 0045-HA-2021-001. Appendix 1.7.2 "Contamination and dose rate measurement at the DN30-X package", Test Instruction 0045-PA-2021-002 and appendix 1.7.3 "Facility operations with the 30B-X Cylinder", 0045-BSH-2020-001 which describes filling, emptying and washing of the 30B-X cylinder are also part of the application.

Regarding cylinder washing, the design (shortened CCRs, close to the valve opening, to avoid any interference with filling and emptying of the cylinder and ensure that there will be no impact of the CCS on the valve or plug) allows the insertion of a flexible lance through the valve opening to help remove any puddle of water.

SAR section 1.7.2.1 noted that the 30B-X cylinder is weighed before filling to confirm the net weight of the heels is below the allowable quantity of 11.3 kg and weighed after filling to ensure the cylinder fill limit is not exceeded. “Facility operations with the 30B-X Cylinder” (document 0045-BSH-2020-001-Appendix 1.7.3, Rev. 1) indicated that proper temperature control and weighing of the cylinder during filling and emptying are means to ensure there are no impacts by the CCS that would impair the 30B-X cylinder to meet the shipment requirements of the packaging and content.

SAR section 1.7 indicated that operations are performed in accordance with ANSI N14.1 and at least as described in USEC 651 “The UF6 Manual – Good Handling Practices for Uranium Hexafluoride”, Rev. 9, 2006.

The testing requirements before each transport are described in section 1.7.2.1 for the 30B-X cylinder and section 1.7.2.2 for the PSP. The leak tightness of the valve seat of a filled cylinder shall be verified by leak testing of the pigtail before disconnection and after closing the cylinder valve seat: a standardized leak rate larger $1 \cdot 10^{-4}$ Pa · m^3/s is not authorized.

The DN30 PSP shall be visually inspected prior to loading according to the handling instruction in appendix 1.7.1: this inspection also includes a functional test of all movable parts.

Handling of the DN30-X package is described in appendix 1.7.1. The procedures to follow to ensure proper tie-down are also specified in this appendix.

Operational steps for filling, emptying and washing the 30B-X cylinders are described in site-specific operating handbooks that are not part of the application. General aspects of these processes are described in appendix 1.7.3 (30B-X Cylinder Facility Operations), along with the demonstration that these processes have no impact on the safe transport of the DN30-X package.

Before transport, it must be assured that the 30B-X cylinder was given ample time for cooling down such that the UF_6 is in solid form. The testing and controls described in section 1.7.2 shall be performed and documented prior to loading a 30B-X cylinder into the DN30 PSP.

Any 30B-X cylinder filled with either UF_6 or heels from UF6 shall comply with the transport regulatory requirements for UF_6.

SAR section 1.7.2.1 discussed the vacuum leakage test and air pressure drop leakage rate test of the valve seat, in accordance with ANSI N14.1 and ANSI N14.5, after filling and prior to shipment. The acceptance criteria included a standardized leakage rate less than 10^{-4} Pa m^3/sec.

The staff reviewed the operating procedures 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

The acceptance tests and maintenance programs are described in detail in appendix 1.8.1 (Inspections of 30B-X Cylinders) “Periodic Inspections of the 30B-X Cylinder”, Test Instruction

0045-PA-2021-001 and Appendix 1.8.2 (Inspections of DN30 PSPs) “Periodic Inspections of the DN30 PSP”, Test Instruction 0023-PA-2015-015.

Details of the 30B-X specification were found in document 0045-SPZ-2021-001-Rev1 “Specification 30B-X”. This document and SAR section 1.8 describe quality assurance and general cylinder requirements related to cylinder design, fabrication, in-service inspections and tests, maintenance and repair. In addition, the document described specific cylinder requirements, including materials, fabrication, radiography, valve, plug, external heat treatment, and certification. Details of the CCS boron carbide are also provided in the document.

The testing requirements and controls before the first use of the packaging are specified in appendix 1.9.2A (Manufacturing Specification 30B-X Cylinder) and appendix 1.9.2B (Manufacturing Specification DN30 PSP)

The test instruction in appendix 1.8.2 (Inspections of DN30 PSPs) details the criteria and measures to be applied to correct potential deviations, including cleaning, parts replacement or repairs.

The 5-year periodical inspections of the DN30-X packaging are subdivided into the periodical recertification of the 30B-X cylinder and the periodical inspection of the PSP. The periodical inspections of the PSP are described in test instruction Nos. 0023-PA2015-015 and 0023-PA2015-016.

The 5-year inspection of the 30B-X cylinder includes, but is not limited to, the following:

(i) 30B-X cylinders, except those already filled at the 5-year expiration date, are to be periodically inspected and tested throughout their service life,
(ii) 30B-X cylinders that have not been inspected and tested within the required 5-year period shall not be refilled until they are properly reinspected and retested.

The 5-year periodic inspections and tests consist of both an internal and external examination of the 30B-X cylinder by a qualified inspector, including a visual inspection of the interior CCS as far as accessible, a hydraulic strength test, and a 100-psig pneumatic leaktest if a valve or plug change has occurred. A 30B-X cylinder shall no longer be used when the shell thickness has decreased below 11 mm.

Details about inspections related to the containment boundary are provided in appendix 1.8.1 (Periodic Inspections of the 30B-X Cylinder, Test Instruction 0045-PA-2021-001-Rev 0).

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:

The package shall be prepared for shipment and operated in accordance with the Operating Procedures of chapter 1.7 of the application.

Each packaging must meet the Acceptance Tests and Maintenance Program of chapter 1.8 of the application.

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

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 %.

Transport by air is not authorized.

The References Section refers to Revision 3 of the application, as supplemented on February 9, 2023.

CONCLUSION

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

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