Answers to the Request for Additional Information DAHER NUCLEAR TECHNOLOGIES GmbH Docket No. 71-9362 Model No. DN30 Package

1 General information

1.1 Provide a discussion in the application to describe and ensure that the loaded 30B cylinder is in a safe condition for transport within the DN30 PSP.
Rev

1.7.4 of the application states that the filling of the 30B cylinder with UF_6 is described in site-specific operating handbooks. Although specific procedural details may be included in user handbooks, the application should provide assurance that the loaded 30B cylinder is in a safe condition for transport. Items to address include:

- The 30B cylinder should be filled, handled, and undergo testing per procedures that, at a minimum, follow USEC-651 "Uranium Hexafluoride: A Manual of Good Handling Practices" (or equivalent).
- Inspection of the 30B cylinder as described in USEC 651 (or equivalent), ANSI N14.1, and ISO 7195 to ensure there are no deposits at the valve and plug.
- Weighing the 30B cylinder to ensure it has not been overfilled and, in addition, has sufficient ullage.
- Prior to shipment, the 30B cylinder is to be cooled such that the vapor pressure is below atmospheric pressure and the entire UF_6 content is solid.

This information is needed to determine compliance with 10 CFR 71.43(f), and 71.55.

Answer to 1.1

Our answer is divided into two parts: first, the four items you listed are explained, and second all the effected sections are updated.

Following are our explanations concerning the four items you listed:

• The 30B cylinder must be filled, handled, and undergo testing per procedures that, at a minimum, follow ANSI N14.1, ISO 7195, USEC-651 or equivalent: routinely examined for leak tightness, damage, as well as other unacceptable conditions prior to sampling, withdrawal, filling, or shipping to ensure that it remains in a safe and usable condition (see section 1.7.2.1).

• Before shipping, the 30B cylinder shall be inspected as described in ANSI N14.1, ISO 7195, USEC-651 or equivalent so that it is assured that there are no deposits at the valve nor at the plug (see section 1.7.2.1).

• The cylinder shall be weighed before and after filling to make sure it has not been overfilled and has sufficient ullage (see section 1.7.2.1).

• Prior to shipment, the 30B cylinder is to be cooled such that the vapor pressure within the 30B cylinder is below atmospheric pressure and the entire UF_6 content is in its solid state (see section 1.7.2.1).

In order to ensure a safe transport, Section 1.7.2 Testing requirements and controls before each transport has been updated in the SAR.

Below is an excerpt of the SAR with the revised section:

1.7.2 Testing requirements and controls before each transport

The testing requirements and controls before each transport are described in

- [ANSI N14.1] or [ISO 7195] as well as [USEC 651] (or in equivalent plant specific instructions) for the 30B cylinder (see section 1.7.2.1 for details).
- Handling instruction No. 0023-HA-2015-001 (see Appendix 1.7.1 (Handling Instruction)) for the DN30 PSP (see section 1.7.2.2 for details).

For annual and 5-year maintenance requirements as well as treatment of non-conformances and deviations, see section 1.8.

1.7.2.1 Inspection of the 30B cylinder

Before filling the 30B cylinder, inspections in accordance with [ANSI N14.1] or [ISO 7195] and at least as described in [USEC 651] (or in equivalent plant specific instructions) shall be carried out:

- The 30B cylinder shall be handled and filled in accordance with [ANSI N14.1] or [ISO 7195] and at least as described in [USEC 651].
- Any defective condition must be corrected before filling according to the requirements of [ANSI N14.1] or [ISO 7195]:
    - The 30B cylinder shall be routinely examined as received and prior to sampling, withdrawal, filling, or shipping to ensure that it remains in a safe and usable condition.
    - Leakage, cracks, excessive distortion, bent or broken valves or plugs, broken or torn skirts, or other conditions that may affect the safe use of the cylinder shall warrant appropriate precautions, including removing the cylinder from service until the defective condition is satisfactorily corrected.
    - Questionable conditions should be referred to a qualified inspector for evaluation and for recommendations concerning use, repair, or condemnation of the cylinder in question.

- Before filling, the cylinder is weighted to establish the net weight of the heels to ensure the fill limit will not be exceeded.
- To avoid overfilling, the 30B cylinder shall be weighted after being filled.

Before loading into the DN30 PSP, the inspection of the 30B cylinder should be carried out in accordance with [ANSI N14.1] or [ISO 7195], and at least as described in [USEC 651] (or in equivalent plant specific instructions):

- Before shipping, the 30B cylinder shall be inspected for leak-tightness, damage, as well as other unacceptable conditions, and it shall be assured that there are no deposits at the valve nor at the plug.
- UF_6 shall be shipped only in its solid state and when the vapor pressure within the 30B cylinder is below atmospheric. If necessary, the 30B cylinder is to be cooled down such that the vapor pressure within the 30B cylinder is below atmospheric.
- The safe state of the 30B cylinder shall be recorded by the UF_6 supplier and the record shall be provided to the shipper.

Special care must be taken to ensure that the cylinder fulfills the leak-tightness criteria of [ANSI N14.1] or [ISO 7195] and the requirements of this SAR.

- The leak tightness of the valve seat of a filled cylinder shall be verified by leak rate testing of the pigtail before disconnection and after closing the cylinder valve seat.
- A leak rate larger than 1×10^{-4} Pa.m^3/s SLR (Standardized Leakage Rate) shall not be permitted.
- The leak test method shall comply to the [ANSI N14.5] or [ISO 12807] standard.
- If air is used for a pressure drop test, the air supply should be clean, dry and free from oil. If it is not, or if the quality of the air supply is uncertain, the test should be performed with nitrogen to ensure reliable results.
- Alternatively, a vacuum test may be performed by attaching a pigtail to the closed cylinder valve and drawing a vacuum (Note: the cylinder's outer surface shall be approximately at ambient temperature and its vapor pressure below atmospheric pressure).

1.7.2.2 Inspection of the DN30 PSP

The DN30 PSP shall be inspected prior to loading according to handling instruction No. 0023-HA-2015-001. The inspection comprises:

- A visual inspection
- A functional test of all movable parts

Following observations shall be cause for further investigation, replacement of parts or rejection of the DN30 PSP as specified in detail in test instruction No. 0023-PA-2015-016 (see Appendix 1.8.2 (Inspection Criteria)):

- Structural changes of exterior or interior shells, like excessive deformations, cracks, holes, etc.
- Excessive damage of flange areas
- Missing or damaged thermal plugs
- Missing or damaged gasket
- Damage of the mortise-and-tenon closure system
- Damage of the valve protecting device as well as functional issues
- Damage of the rotation preventing device as well as functional issues
- Excessive wear and tear of the thermal protective material
- Damage to any welding seams like cracks, holes, excessive corrosion
- Excessive damage of handling devices

Test instruction No. 0023-PA-2015-016 contains in detail the inspection criteria and the measures in case of deviations. Measures could comprise cleaning, replacement of parts, minor repairs (on site), major repairs (to be carried out by the license holder or an authorized repair shop qualified for such repair).

Previous sections 1.7.4 and 1.7.5 have been merged to form new section 1.7.4 Loading procedures for the 30B cylinder and the DN30 PSP.

Below is an excerpt of the SAR with the new section:

1.7.4 Loading procedures for the 30B cylinder and the DN30 PSP

Before each use, the 30B cylinder and the DN30 PSP shall be inspected as described in section 1.7.2.1 and section 1.7.2.2, respectively.

1.7.4.1 Loading and unloading of UF_6 content into the 30B cylinder

Filling of the 30B cylinder with UF_6 is described in the site specific operating handbooks, which are not part of this SAR. It must be assured that before transport the 30B cylinder was given ample time for cooling down such that the UF_6 is in solid state.

The testing and controls required in section 1.7.2 shall be performed and documented prior to loading a 30B cylinder into the DN30 package. Further any 30B cylinder filled with either UF_6 or heels from UF6 should comply with the transport regulatory requirements for UF_6.

1.7.4.2 Loading of the 30B cylinder into the DN30 PSP

An overview of the safety related loading steps during loading of a 30B cylinder into the DN30 PSP is listed in the following. Details of the handling steps are specified in handling instruction No. 0023-HA-2015-001.

1) The rotation preventing devices are in position “open”.
2) The valve protecting device and its housing are in position “open”.
3) Lower the 30B cylinder in horizontal orientation with the valve in 12°o’clock position into the bottom half of the DN30 PSP.
4) When the lower rim of the cylinder skirt has passed the valve protecting device, rotate this valve protecting device towards the cylinder head by approx. 90° until it is in contact with the cylinder head. Then lower the cylinder until it rests on the inner shell of the bottom half of the DN30 PSP. Then push the housing in position “closed”.
5) Move the rotation preventing devices to position “closed”.
6) Lower the top half of the DN30 PSP onto the bottom half.
7) Insert the pins into the six mortise-and-tenon closure devices and fix the pins with the securing bolts.
8) Install the seals.

1.7.4.3 Unloading of the 30B cylinder from the DN30 PSP

In order to prevent damage of any safety related feature during unloading, the following general steps are required. Details are given in handling instruction No. 0023-HA-2015-001.

1) Check and remove the seals.
2) Loosen the securing bolts and remove the pins of the six mortise-and-tenon closure devices.
3) Lift off the top half of the DN30 PSP.
4) Move the rotation preventing devices to position “open”.
5) Pull the housing from the valve protecting device in position “open”.
6) Lift the 30B cylinder and rotate the valve protecting device by about 90° until it rests on the flange of the bottom half.
7) Lift the 30B cylinder out of the bottom half of the DN30 PSP.

Section 1.8 Maintenance has also been changed accordingly.

Below is an excerpt of the SAR with the revised section:

1.8 Maintenance

1.8.1 Annual maintenance requirements for the DN30 PSP

The annual inspections of the DN30 PSP are described in test instruction No. 0023-PA-2015-015 (see Appendix 1.8.1 (Periodical Inspections)) and test instruction No. 0023-PA-2015-016 (see Appendix 1.8.2 (Inspection Criteria)), in which the criteria for the checks are defined and measures in case of non-conformances or deviations are specified.

In the case that non-conformances or deviations might affect the safety of the DN30 packaging the user of the packaging has to inform the owner of the certificate of package approval in writing about the non-conformance or deviation. It is then the decision of the owner of the certificate of package approval to undertake suitable measures to return the packaging to service in full compliance with the SAR and the certificate of package approval.

1.8.2 5-year maintenance requirements for the 30B cylinder and the DN30 PSP

The 5-year periodical inspections of the DN30 packaging are subdivided into the periodical recertification of the 30B cylinder and the periodical inspection of the DN30 PSP.

The 5-year maintenance inspection of the 30B cylinder shall be performed in accordance with [ANSI N14.1] or [ISO 7195] and at least as described in USEC 651 (or in equivalent plant specific instructions). This maintenance inspection includes, but is not limited to, the following:

- 30B cylinders, except those already filled at the 5-year expiration date, are to be periodically inspected and tested throughout their service life.
- 30B cylinders that have not been inspected and tested within the required 5-year period shall not be refilled until they are properly re-inspected and retested. Prior to shipment, 30B cylinders that have not been recertified within the 5-year requirement shall be visually inspected for degradation of the cylinder wall. Any questionable conditions should be investigated. Details on the visual inspection are provided in attachment 2 of 0023-PA-2015-015 (see Appendix 1.8.1 (Periodical Inspections)).
- The 5-year periodic inspections and tests consist of the following:
    - An internal and external examination of the 30B cylinder by a qualified inspector.
    - A hydrostatic strength test as described in [ANSI N14.1] or [ISO 7195].
    - When a valve or plug change has occurred, a 100 psig pneumatic leak-test as described in [ANSI N14.1] or [ISO 7195] is required.
- After a 30B cylinder is tested, its outer shell may be cleaned and repainted. At each 5-year periodic inspection, the cylinder shall have the tare weight re-established.

- A 30B cylinder shall be removed from service (for repair or replacement) when it is found to contain leaks, corrosion, cracks, bulges, dents, gouges, defective valves, damaged skirts, or other conditions that, in the opinion of a qualified inspector, render it unsafe or unserviceable in its existing condition.
- A 30B cylinder shall no longer be used in UF_6 service when the shell thickness has decreased below 5/16 in.

The periodical inspections of the DN30 PSP are described in test instruction No. 0023-PA-2015-015 (see Appendix 1.8.1 (Periodical Inspections)) and test instruction No. 0023-PA-2015-016 (see Appendix 1.8.2 (Inspection Criteria)), in which the criteria for the checks are defined and measures in case of non-conformances or deviations are specified.

In case non-conformances or deviations might affect the safety of the DN30 packaging, the user of the packaging has to inform the owner of the certificate of package approval in writing about the non-conformance or deviation. It is then the decision of the owner of the certificate of package approval to undertake suitable measures to return the packaging to service in full compliance with the SAR and the certificate of package approval.

1.2 Remove from the application all statements pertaining to any equivalency of materials or their possible substitution.

Staff has always been opposed to vague wording, such as “equivalent” or “similar,” in safety analysis reports. What is “equivalent” to one applicant may not be “equivalent” for another applicant. All materials must have specified characteristics in accordance with recognized Codes and Standards, particularly for “important to safety” components. Defining equivalency by some critical characteristics meeting or exceeding those specified for the designated material is not acceptable for staff because it does not provide the means to determine how equivalency will be confirmed.

Therefore, these equivalency statements could lead to an incorrect conclusion that something other than the unique material specified in the licensing drawings could be used. Staff noticed that there was a list of materials that could be substituted to those on the licensing drawings according to Section 5.2 of the Manufacturing Specifications, Document (0023-SPZ-2016-001). As such, any packaging component which does not comply with the licensing drawings, referenced in the certificate, is not acceptable for shipment.

This information is needed to determine compliance with 10 CFR 71.43.

Answer to 1.2

The plate material used for the DN30 PSP is the material No. 1.4301 according to DIN EN 10088-2 (ASTM A240 grade 304). However, the production of this material will cease in the next year and it will be completely replaced by newer material 1.4307 according to DIN EN 10088-2 (ASTM A240 grade 304L). The only difference in the chemical composition of both materials is in the carbon content. Material No. 1.4301 has a carbon content of less or equal to 0.08 %, material No. 1.4307 less or equal to 0.03 %. This means that material No. 1.4307 has a higher quality than material No. 1.4301. In the transition phase, both materials are on the market, hence both materials are specified in the drawings and the SAR.

For the structural analysis the lower material properties of material No. 1.4307 have been used throughout.

We will delete the substitution material No. 1.4541 for all structural parts (outer and inner shell structure) as it will not be required for serial production. For parts not relevant for safety we prefer to keep this substitution material.

For the closure system material No. 1.4541 according to DIN EN 10088-3 (ASTM A479 grade 321) is specified. We would prefer to keep the material with the higher quality 1.4571 according to DIN EN 10088-3 (ASTM A479 grade 316Ti) as alternative material.

1.3 Provide (i) Codes and Standards comparable to those used in the U.S. for the international Codes and Standards quoted in the application, and (ii) additional Codes and Standards as those that were provided in another UF_6 transport package application.
The applicant used international Codes and Standards. However, not all of them are either described nor comparable to those used in the U.S. Examples of such Codes and Standards that may be used are in IAEA 2012, Certificate EN10204, ISO 7195, and Steel Codes.

Also, the applicant did not discuss the DN30 overpack with respect to the ASME Codes, while the staff notes that another UF_6 package application discussed in detail the acceptance criteria with respect to both ASME Section V and Section III (Subsection NF) in its maintenance chapter. The applicant needs to include such a discussion in its application.

This information is needed to determine compliance with 10 CFR 71.43(d) and 71.43(f).

Answer to 1.3

The packaging components are specified in chapter 1.4 of the SAR.

The materials of the 30B cylinder are specified in Section 1.4.1.1. All materials are specified according to ANSI N14.1 (ISO 7195 is the international version of ANSI N14.1 and relies exclusively on the specification of materials in ANSI N14.1).

The materials of the DN30 PSP are specified in Section 1.4.1.2. Table 6 in this section lists all materials of the DN30 PSP together with the applicable European standards and the equivalent ASTM standards.

All references to IAEA 2012 will be amended in the SAR by the respective references to 10 CFR 71 and 49 CFR 173. This does not apply to the appendices of the SAR.

The DIN EN 10204 is a European standard defining who has to witness and certify the material tests given in the material standards. According to our knowledge there is neither an equivalent standard in ANSI nor in ASME. An example shall illustrate the application of such standard:

In the last columns of the parts list of the DN30 PSP the requirements concerning certification of the material are given. For part No. 101, the lower part of the closure device, a certification according to DIN EN 10204 3.1 is required. In this standard 3.1 is described as:

Document issued by the manufacturer in which he declares that the products are in compliance with the requirements of the order and in which he supplies test results.

The test unit and the tests to be carried out are defined by the product specification, the official regulation and the corresponding rules and/or the order.

The document is validated by the manufacturer’s authorized inspection representative, independent of the manufacturing department.

We are aware of another design of Protective Packaging for the shipment of UF_6 and the requirements concerning acceptance criteria with respect to both ASME Section V and Section III (Subsection NF) in its maintenance chapter. This design has been approved by the NRC as type B(U)F package licensed to carry up to 10^5 A_2. In contrary, our application for licensing of the DN30 package is a type AF license, only.

The main part of the package with respect to containment and confinement is the 30B cylinder fully compliant with ANSI N14.1. This part of the package DN30 is built according to the relevant ASME requirements and is recertified every 5 years according to the respective ASME requirements described and specified in ANSI N14.1.

The DN30 PSP is not a pressure retaining part of the DN30 package (Section 1.4.2.3.1 of the SAR was updated to include this information). The DN30 PSP has the functions to protect the 30B cylinder from mechanical impacts during NCT and HAC and to protect the 30B cylinder from thermal impacts during HAC.

The inspections specified in the handling instructions and the recertification instructions are by far sufficient to ensure that the DN30 PSP fulfills these functions at any time.

2 Structural and materials review

2.1 Clarify and justify the assumptions made in the characterization of UF_6 contents with respect to LS-DYNA hypothetical accident conditions (HAC) drop simulations of the DN30 Package.

For HAC drops simulated in LS-DYNA, the applicant assumed that the UF_6 in the 30B cylinder remains a single solid piece. In addition, the material properties assigned to the contents are not those of normal concrete but are similar to “reinforced” concrete; however, according to picture 4 of the drop test program (document 0023-BDI-2015-002), the contents are described as being partially loose and with large fissures.

Provide a justification for the following:

a) The assumption that the UF_6 material is always bonded to the 30B cylinder. If the contents are one solid piece and detach from the 30B cylinder during any of the simulated drops, it could cause internal damage to the 30B cylinder and/or valve plug. Drop simulations should be re-examined in this instance.

b) The UF_6 material is modeled as one large piece during the drop simulations. Clarify if vibrations incident to transport could potentially “break up” or fracture the UF_6 material, prior to a drop. In such a case, large pieces of UF_6 should be modeled during drop simulations.

c) The use of “reinforced” concrete material properties for the UF_6. Large inelastic deformations can occur in the UF_6 material based on this material model, allowing energy to be absorbed into the UF_6 rather than the surrounding containment boundary and potentially imposing less structural demand on the containment boundary (30B cylinder). Assuming more realistic (i.e., more brittle) material properties for the UF_6 could potentially cause more damage to the containment boundary.

Confirm the modeling of the contents and update the LS-DYNA drop simulations as necessary.

This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(1).

Answer to 2.1

The assumptions used for the characterization of UF_6 with respect to the experimental drop tests and the drop test simulations are discussed in Chapter 2 of Technical Note 0023-BBR-2019-004-Rev1 (Attachment 1 of this document).

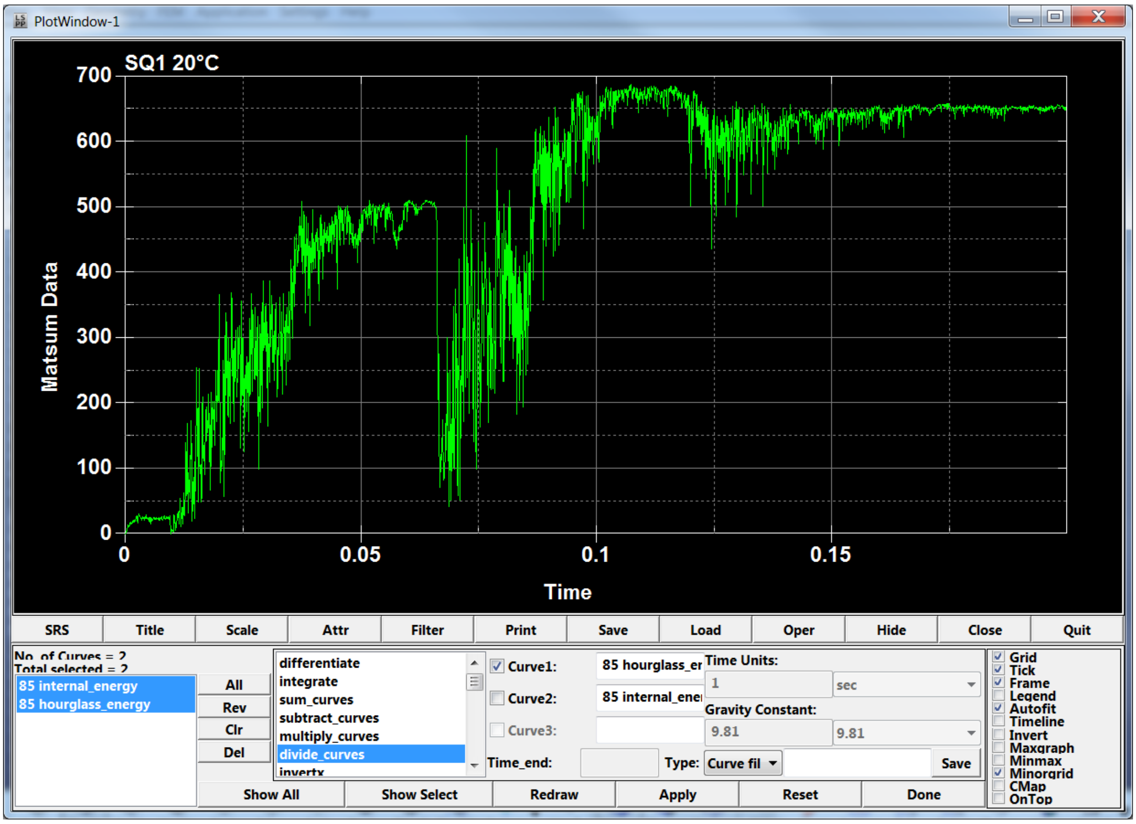
With regard to RAI 2-1 a), except for drop test sequence 4, the content is never bonded to the 30B cylinder. In drop test sequence 4 (flat drop onto the closure system) the content began to rotate inside the 30B cylinder, which introduced unrealistic rotational inertia into the system. This unrealistic behavior was identified by comparing the deceleration curves from the experiment and the simulation.

Lower filling ratios of the 30B cylinder below 50 %, that potentially allow more movement of the content inside the cylinder, are also covered by the current simulation model. A gap has been introduced between the cylinder shell and the content to avoid initial penetrations in the model. Combined with the content's deformation, large relative movements between the content and the 30B cylinder occur, which is clearly seen during the simulation of drop I in Sequence 8.

2.2 Justify the ratio of hourglass energy to internal energy observed for certain parts of the DN30 during drop simulations in LS-DYNA.

As stated by the applicant, the ratio of hourglass energy to internal energy should be kept to a ratio of 10% or less, as hourglass energy indicates a nonphysical part of internal energy. This, in turn, implies that deformations and overall physical behavior of a part may not be realistic during LS-DYNA simulations.

For drop sequence SQ1, the plug of the 30B cylinder (part 85 in LS-DYNA) observes very large amounts of hourglass energy relative to the internal energy of the part as seen in the graphic below. Other parts, such as the protective case surrounding the valve (part 56 in LS-DYNA), and parts 92-103, also observe large amounts of hour glassing energy.



Parts 92-103 represent the closure devices (mortise and tenon design) used to keep both halves of the Protective Structural Packaging (PSP) together and have been idealized as solid steel blocks in LS-DYNA. A more refined analysis is conducted on these closure devices that takes account of the actual geometry elsewhere in the application and uses raw LS-DYNA output.

The design of the closure devices and other parts of the package should be re-examined and updated. Staff also notes that large ratios of hour glassing energy to internal energy are not confined to just the sequence SQ1 or to just the parts mentioned above, as other drop sequences and parts exhibit this behavior.

It was noted that the applicant compared the energy of a particular part to the overall energy of the package to justify large ratios of hour glassing energy. While the energy of a part may be very small relative to the energy of the package as a whole, realistic behavior of that part (which hour glassing energy helps describe), such as the plug or valve of the 30B cylinder, is critical. Other parts of the package which do not make up the containment boundary should also be examined for hour glassing as unrealistic behavior of these parts can influence those that are part of the containment boundary.

This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(1).

Answer to 2.2

To improve the reliability of the simulation results for the DN30 package, their sensitivity regarding the applied element formulation and hourglass control types is investigated in a sensitivity analysis in chapter 3 of Technical Note 0023-BBR-2019-004-Rev1. The influence of fully integrated shell elements (ELFORM=16) and fully integrated solid elements (ELFORM=-1) on the simulation results is investigated as well. The second part of this sensitivity analysis considers the impact of the hourglass control types on the reaction force measured at the closure device, which is used in the stress analysis of the detailed model of the closure device (see Section 2.2.1.5.1.5.8 of the SAR).

The results of the sensitivity analysis show that the current simulation results are not affected by increased hourglass energy ratios that occur for certain parts and that the applied force currently used in the detailed stress analysis of the closure device still bounds the results from the sensitivity analysis.

Additional clarifications on other aspects of the simulations related to this RAI are provided below.

Discussion about negative volume errors in simulations involving fully integrated solid elements for foam parts

The following is an excerpt from the support website of LSTC:

"In materials that undergo extremely large deformations, such as soft foams, an element may become so distorted that the volume of the element is calculated as negative. This may occur without *the material reaching a failure criterion. There is an inherent limit to how much deformation a Lagrangian mesh can accommodate without some sort of mesh smoothing or remeshing taking place. A negative volume calculation in LS-DYNA will cause the calculation to terminate unless ERODE in *CONTROL_TIMESTEP is set to 1 and DTMIN in *CONTROL_TERMINATION is set to any nonzero value in which case the offending element is deleted, and the calculation continues (in most cases). Even with ERODE and DTMIN set as described, a negative volume may still occur and cause a premature termination."*

It is generally known that fully integrated element formulations tend to be less stable in situations involving large deformations or distortions. Thus, for soft materials like foam, one should usually avoid fully integrated elements. The reason why fully integrated solid elements are often less robust than a 1-point element is because a negative Jacobian can occur at one of the integration points while the element as a whole maintains a positive volume. The calculation with a fully integrated element will therefore terminate with a negative Jacobian much sooner than will a 1-point element. This also implies that if the element volume is indeed negative, error termination would be triggered with ELFORM=1 for the solid elements as well. Since this is not the case in any simulation of the DN30 package, we prefer using the 1-point element formulation ELFORM=1.

The explanation above is further strengthened by the fact that the volumetric strains in the foam parts never reach 100 % in any of the simulations using 1-point integration elements. Theoretically, the foam can reach 100 % strain, but the stress-strain curves used for the foam material model significantly stiffen the foam behavior for compression levels above the densification strain (determined as 89% for RTS 120 and 82% for RTS 320). In fact, only very few elements exceed the corresponding densification strain in all the simulations performed for the DN30 package.

Additional information about the valve and plug of the 30B cylinder

The models for the plug and the valve are both very reduced representations of the real valve and plug, respectively. Their finite element approximations essentially cover their outer dimensions, but details are not considered. In case of the plug, there is only one row of elements that represents the plug. To cover the essential features of the valve shape, tetrahedral elements with smaller element sizes are used. The valve and the plug are both connected to the 30B cylinder shell by a tied-contact.

This simplified modelling approach is acceptable as the main concern of the simulations is to prove that no contact occurs at the valve and the plug. Since this criterion is fulfilled in all simulations, the valve and the plug only experience loads resulting from their own inertia. Such loads do not cause any plastic deformations at the valve and the plug, which in turn results in very small internal energies for these parts that are negligible compared to the internal energies of other parts of the DN30 package. Consequently, there are only very small elastic deformations at the plug and the valve and calculating the ratio of the hourglass energy to the internal energy is therefore not an appropriate measure of hourglassing for these parts. In addition, visual inspection of the plugs and the valves finite element model reveals no hourglassing.

Any further analysis with respect to forces, deflections, stresses or strains is not required to evaluate the main acceptance criteria for the DN30 package: no contact at the valve and the plug with any other part of the DN30 package except their initial connection to the 30B cylinder. High hourglass ratios (not hourglass energies) for these parts do not reduce the accuracy of the evaluation of this acceptance criteria because the occurring elastic deformations are very small compared to the safety margins in the remaining distances to neighboring parts (see Section 8.3 of Appendix 2.2.1.3 of the SAR).

2.3 Clarify how a safety factor of 3 is met with respect to yielding for the lifting lugs of the DN30 package.

Section 2.2.1.2.3.1 of the application analyses the stresses found in the lifting lugs (part 211) which reach a utilization of 87.6% of the shear stress capacity in Table 24. 10 CFR 71.45(a) states that a factor of 3 is needed with respect to yielding, which would indicate that a utilization of 33.3% or less of the shear capacity of the lifting lug is required.

Clarify how a factor 3 with respect to yielding is achieved and update the application as necessary.

This information is needed by the staff to determine compliance with 10 CFR 71.45(a).

Answer to 2.3

In compliance with 10 CFR 71.45(a), the calculation is modified to account for the nominal instead of the maximum shear stress in the corresponding cross section. This reduces the calculated shear stress by a factor of 1.5. In addition, a safety factor of 1.3 is already included in the calculation of the utilization. With these changes a total minimum safety factor of 4.4 against yield is achieved, while the hoisting coefficient of 2 accounting for dynamic loads is still included. The static analysis of the lifting lugs has been updated in Section 2.2.1.2.3.1.1 in the SAR.

2.4 Clarify the weld symbol terminology indicated on drawing 0023-ZFZ-1000-002.
Drawing 0023-ZFZ-1000-002 has 14 different types of welds tabulated. Each weld symbol has an “a” or a “z” associated with it as well as a numerical pair of values at the tails of the weld symbols such as “135/141”.

It is unclear if these values are weld deposit thickness or some other fabrication terminology. Place this clarifying terminology on the licensing drawings.

This information is needed by the staff to determine compliance with 10 CFR 71.33(a)(5).

Answer to 2.4

The weld symbol terminology indicated on drawing 0023-ZFZ-1000-002 has been updated. The currently used symbols refer to the following:

- “a” associated with a number refers to the fillet weld thickness (height of the inscribed triangle).
- “z” is used when the leg length of the fillet weld is meant.
- For groove welds, there is no differentiation required.

The two numbers at the tails of the weld symbols refer to the welding processes to be applied according to DIN EN ISO 4063:

- 135 refers to gas metal arc welding (also known as metal active gas welding or MAG welding)
- 141 refers to gas tungsten arc welding (also known as tungsten inert gas welding or TIG welding)

However, these welding processes depend on the materials and type of weld and therefore are best chosen by the authorized manufacturer of the DN30. Therefore, the welding processes have been removed from drawing 0023-ZFZ-1000-002.

2.5 Clarify the weld used to attach the lifting lug to the front plate of the foot.

Section 2.2.1.2.3.1 of the application analyses the stresses found in the lifting lugs (part 211). The calculations assume that a full penetration butt weld attaches the lifting lug to the front plate (part 101) of the foot.

Drawing 0023-ZFZ-1110-210 indicates that the lifting lug is welded according to weld seam type SN13 which is not a full penetration butt weld. Clarify the weld used at this location and update the drawings and/or the calculations as necessary.

This information is needed by the staff to determine compliance with 10 CFR 71.33(a)(5) and 71.45(a).

Answer to 2.5

SN13 is meant to correspond to a double-bevel-groove weld. The lifting lug plate is 20 mm thick and is welded to the base plate by a full penetration butt weld. Consequently, no update of the calculations is required.

To avoid confusion, the weld symbol of SN13 has been changed to a double-bevel-groove weld and the drawings have been updated accordingly.

2.6 Clarify how tie-down devices are able to withstand 2 times the weight of the package in the vertical direction, 5 times the weight of the package in the lateral direction, and 10 times the weight of the package in the axial direction.
Section 2.2.1.3 indicates that the tie downs are designed for only 2 times the load in the axial, lateral, and vertical direction rather than 5 times the weight of the package in the lateral direction and 10 times the weight of the package in the axial direction as per 10 CFR 71.45(b)(1).

In addition, it appears that Figure 5 shows the package loaded laterally by axial loads, while the axial direction of the package appears to be loaded in the lateral direction which is contrary to Figures 18 and 19 in the application.

This information is needed by the staff to determine compliance with 10 CFR 71.45(b)(1).

Answer to 2.6

The tie-down analyses in Section 2.2.1.3.1 of the SAR has been updated to comply with the requirements of 10 CFR 71.45(b)(1). In the analysis, the worst possible orientation (with its longitudinal axis in transverse direction of travel) of the DN30 packages on the dedicated flat racks has been considered and the corresponding figures have been updated. The calculation results prove that the tie-down system is designed to 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 without exceeding the yield strength of the material.

It is shown as well that a failure of the tie-down system due to excessive forces will not lead to an impairment of the DN30 package to meet the other requirements of 10 CFR 71 and 49 CFR 173.

2.7 Justify the amount of torque specified for the pins that secure the closure system of the PSP portion of the package.

Document 0023-HA-2015-001-Rev2 indicates that a tightening torque of 80 Nm is called for by each of the 6 pins that secure the closure system of the PSP. It is unclear how these values were determined, and how fatigue effects during NCT will not loosen the bolts.

This information is needed by the staff to determine compliance with 10 CFR 71.43(c).

Answer to 2.7

The containment system of the DN30 package consists of the 30B cylinder with its shells, heads and welding seams as well as the valve and the plug. The DN30 PSP is not part of the containment system but protects the containment system.

The fastening devices of the 30B cylinder are its valve and plug, which cannot be accessed during transport and, hence, cannot be opened unintentionally. During transport, the pressure inside the containment system is below atmospheric pressure, which is well below the MNOP of 1.38 MPa according to ANSI N14.1 and ISO 7195.

The DN30 PSP with its six closure devices prevents the package from being opened and, thus, represents the thermal and mechanical protection of the 30B cylinder. For this purpose, each pin keeps each pair of the robust mortise-and-tenon devices together. The bolts secure the pins. These bolts are not exposed to any forces, so that 80 Nm is sufficient to keep the pins in place during RCT, NCT and HAC.

The tightening torque of 80 Nm for the bolts of the closure device is derived from the torque guidelines by the manufacturer for 254 SMO washers (Attachment 3 of this document):

- Bolt size: M16
- Bolt grade: A4-70
- Lubrication: copper/graphite paste
- Torque M_T: 124 Nm

The closure system of the DN30 consists of M16 bolts made from Nitronic 50, the base material is 1.4541.

The tightening torque is therefore modified based on the used material:

- $R_{p0.2}$ (A4-70) = 450 MPa
- $R_{p0.2}$ (Nitronic 50) = 370 MPa
- $R_{p0.2}$ (1.4541) = 190 MPa

Scaled torque for both components based on their yield strength:

$$M_{\mathrm{T,Nitronic50}} = M_{\mathrm{T,A4-70}} \cdot \frac{R_{\mathrm{p0.2,Nitronic50}}}{R_{\mathrm{p0.2,A4-70}}} = 124\ \mathrm{Nm} \cdot \frac{370\ \mathrm{MPa}}{450\ \mathrm{MPa}} = 100.2\ \mathrm{Nm}$$

$$M_{\mathrm{T,1.4541}} = M_{\mathrm{T,A4-70}} \cdot \frac{R_{\mathrm{p0.2,1.4541}}}{R_{\mathrm{p0.2,A4-70}}} = 124\ \mathrm{Nm} \cdot \frac{190\ \mathrm{MPa}}{450\ \mathrm{MPa}} = 52.4\ \mathrm{Nm}$$

$$M_{\mathrm{T,total}} = \frac{M_{\mathrm{T,Nitronic50}} + M_{\mathrm{T,1.4541}}}{2} = \frac{100.2\ \mathrm{Nm} + 52.4\ \mathrm{Nm}}{2} = 77.2\ \mathrm{Nm}$$

The tightening torque for the bolts of the closure device was therefore set to 80 Nm.

Unintentional loosening of the bolts is prevented by the Nord-Lock washers themselves. A hands-on demonstration of the basic working features of the Nord-Lock washers was given during the meeting on the 17th of April.

2.8 Justify the mechanical properties used to characterize substitute materials in lieu of those called for in the licensing drawings.
Table 2 of document 0023-SPZ-2016-001 indicates that materials used to construct the PSP portion of the package can be substituted for other materials; however, as said in RAI 1-2, it is unclear what criteria applies to the substitute materials chosen.

Staff does not accept equivalency of materials because the applicant cannot clarify how yield strength, ductility, stress-strain curves, and strain-rate for substitute materials meet or exceed those of the materials called for on the licensing drawings. Also, the applicant has not considered the differences in materials in any FEM analyses, nor updated the application accordingly.

This information is needed by the staff to determine compliance with 10 CFR 71.33(a)(5).

Answer to 2.8

Please also see Answer 1.2.

The material properties for all materials including their substitutes have been provided in Section 2.2.1.1.2 of the SAR. The substitution materials have been chosen according to their mechanical properties and similarities in chemical composition. Materials No. 1.4301, 1.4307, 1.4541 and 1.4571 are all standard grade austenitic corrosion resisting steels. The difference regarding yield strength, ultimate tensile strength and elongation at fracture is less than 10 %.

Because of the similar minimal elongation at fracture, it can be concluded that these materials have similar ductility. Also, since the stress-strain curves are determined based on the yield and ultimate strength, the resulting stress-strain curves are similar as well. The similarity of the strain-rate behavior is deduced from the similarity in the chemical composition of these materials.

The table below lists the yield strength, ultimate tensile strength and elongation at fracture for these four stainless steels according to standards DIN EN 10088-2 and DIN EN 10088-3.

Temperature [°C]	**20**	**100**	**60**	**20**	**100**	**60**
Material [DIN EN 10088-2]	**1.4301**			**1.4307**		
Rp0.2 [MPa]	230	157	193,5	220	147	183,5
Rp1.0 [MPa]	260	191	225,5	250	181	215,5
Rm [MPa]	540			520		
A [%]	45			45		
Material [DIN EN 10088-3]	**1.4541**			**1.4571**		
Rp0.2 [MPa]	190	175	182,5	200	185	
Rp1.0 [MPa]	225	205	215	235	215	
Rm [MPa]	500			500		
A [%]	40			40		

The material properties of material No. 1.4307 have been taken for the calculations because they are covering for all other material properties. FEM analyses taking specific substitute materials into account are not required as there is hardly any difference in the simulation results to be expected because of the very similar material characteristics.

The substitution materials have been added to the part list.

2.9 Describe the condition of the 30B cylinder after the HAC fire given the preexisting inelastic deformations in the 30B cylinder from the previous drop tests.
Several of the drop tests sequences examined (such as sequence 3) indicate that the 30B cylinder undergoes inelastic deformations. It is unclear what the condition of the 30B cylinder is after the HAC fire, given these preexisting inelastic deformations were not accounted for during the HAC analysis.

This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(4).

Answer to 2.9

The USEC UF_6 Manual, ANSI N14.1 and ISO 7195 all provide examples of acceptable damage to UF_6 cylinders. Even with such damage, the 30B cylinders are designed to withstand any pressure development inside the cylinder that does not exceed the testing pressure of 400 psig/2.76 MPa (cf. ANSI 14.1). In the thermal analysis (Section 2.2.2.3.5.2 of the SAR) it is shown that the pressure development inside the 30B cylinder during the thermal test stays below the testing pressure.

Based on the drop test simulations, the simulation results with the largest plastic deformations for the 30B cylinder are used to measure the corresponding indention in the cylinder shell. In chapter 6 of Technical Note 0023-BBR-2019-004-Rev1, it is shown that the diameter to depth ratio of this dent is significantly larger than 12, while the depth is significantly lower than 12.7 mm. Consequently, this dent is referred to as a shallow curved dent in the cylinder shell and represents an acceptable damage to the 30B cylinder.

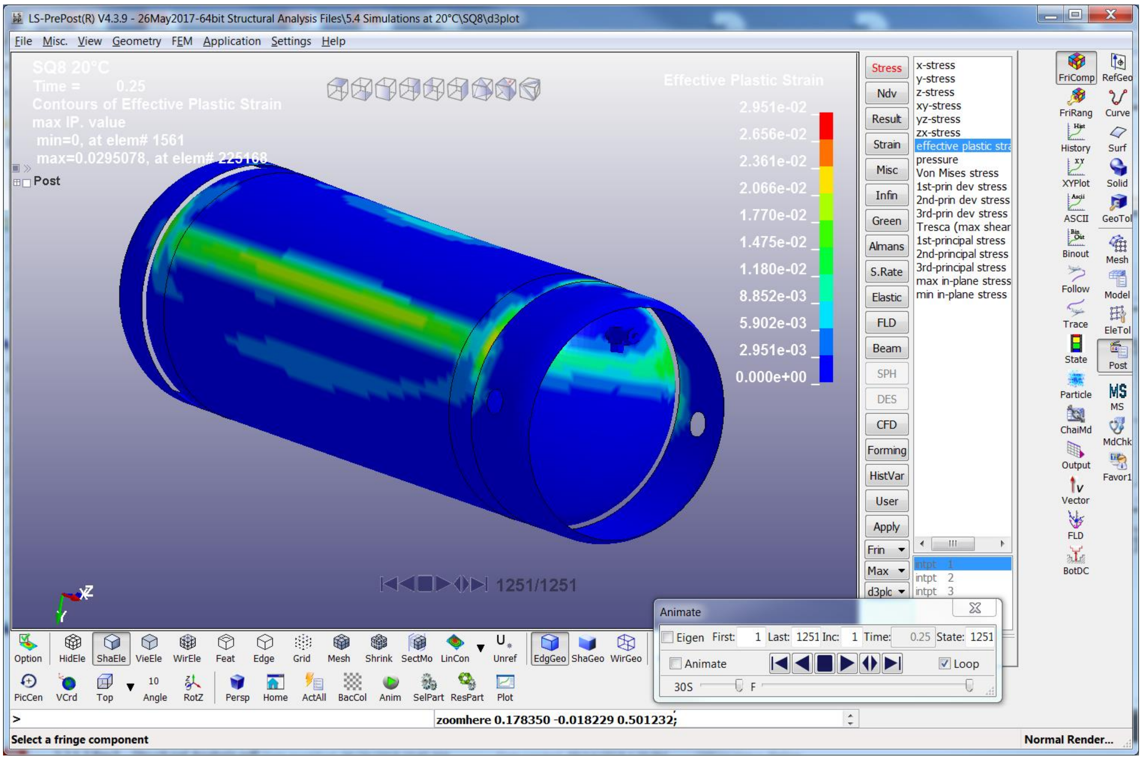
This proves that the pre-damaged 30B cylinders are still capable to withstand the HAC thermal test.

2.10 Justify the use of tied contacts in LS-DYNA drop simulations to represent welds in the package.

The image below displays the inelastic deformations observed in the 30B cylinder after Sequence 8 has terminated. The applicant states that a fine mesh would be required to model the welds between parts such as those in the 30B cylinder but would be too time consuming. Instead, tied contacts have been used. From the picture below, the canister appears to have inelastic deformations, in the main body of the cylinder, which do not carry at all into the adjoining/protruding flange which, if welded, should experience very similar inelastic demands where the 2 parts meet.

The parts appear to be too separated from each other and do not appear to be transmitting forces correctly. The valve at the end of the cylinder appears to be in a zone of inelastic deformation; yet, it is unclear how the valve behaves as a result. Staff is concerned that the containment boundary (valve) may not be free of inelastic deformation as desired. Similar behavior has been noted for the 30 B cylinder in other sequences.

The applicant shall verify that the tied contact assumption is valid when compared to welds that have been modeled as the rest of the 30B cylinder (with a mesh).



This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(1).

Answer to 2.10

In chapter 4 of Technical Note 0023-BBR-2019-004-Rev1, a sensitivity analysis has been performed, investigating several different approaches to model the connection between the 30B cylinder shell and the cylinder skirts. The following modelling approaches are investigated:

- The penalty based tied contact is replaced with a constraint based tied contact with offset option.
- Additional shell elements (ELFORM=2) are introduced so that the contact interface is replaced by mesh connections.
- The 30B cylinder is entirely modelled with solid elements (ELFORM=1).

The results show that a continuous distribution of plastic strain can only be obtained with mesh connections or solid elements. However, the results also show that the better the representation of the actual connection is, the lower the resulting maximum plastic strain is. By using solid elements for the 30B cylinder, the plastic strain drops from 3.3 % obtained with the shell model to 1.9 %. Consequently, the maximum plastic strains obtained with the current FEM model in the SAR are conservative and no update of the FEM simulations is required.

The above investigations refer to drop test Sequence 8, where the discontinuous inelastic deformations have been observed. It has been found out that this behavior mainly occurs for horizontal drop test sequences, and that the modelling of the connection between the 30B cylinder shell and skirt is less relevant for vertical or inclined drop orientations. Nevertheless, the obtained results can be transferred to all sequences, although they are less relevant there compared to Sequence 8.

2.11 Clarify how dimensional changes in the package due to thermal expansion were incorporated into the LS-DYNA simulations and resulting stress/strain outputs.
From the application and LS-DYNA models, it is clear that changes in material properties as a function of temperature were incorporated; however, the physical dimensions of the package do not appear to have changed with temperature (-40 °C, and 60 °C) as simulated.

Describe how the package behaves for simulated drop tests in LS-DYNA for NCT and HAC given gap and dimensional changes associated with temperature. Staff is concerned that additional stresses and/or strains in the package may not be fully captured as a result.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(1) & (c)(2), 10 CFR 71.73(b), and 10 CFR 71.73(c)(1).

Answer to 2.11

A new Section 2.2.1.6 Additional proofs for the structural analysis has been introduced in the SAR (see also Answer 3.5). In this section, the stresses caused by temperature influences are investigated that might occur because of the expansion of the 30B cylinder inside the DN30 PSP or the expansion of the foam. In this regard, very conservative assumptions are used to bound the resulting stresses.

It is shown that the gap between the 30B cylinder and the inner shells of the DN30 PSP is large enough to avoid any development of thermal stresses.

In case of the foam expansion it was assumed that the steel parts do not extent at all and that all parts have the same temperature. However, the thermal analysis has shown that the average temperature of the foam parts is lower. Even with this assumption the calculated stress is only 39 MPa and thus significantly (by a factor of 5) below the yield strength. This means that such a pre-stressed DN30 PSP behaves slightly stiffer, which is covered by the simulations at room temperature and -40 °C.

For temperatures below room temperature, there are no thermal stresses.

Since the calculation of the thermal stresses is based on conservative assumptions, they can be expected to be lower than 39 MPa. Consequently, there is hardly any impact on the simulation results to be expected.

2.12 Describe the design criteria used to characterize the materials of the DN30 in the inelastic range.

Relatively large inelastic strains (0.449) have been observed in the package as a result of drop test simulations for HAC, as observed in figure 5-254 of document 0023-BSH-2016-001-Appendix-2.2.1.3-Rev3. It is unclear from the documentation or material models from LS-DYNA when the uniform elongation of any of the materials of construction in the package would be exceeded.

In such a case, additional material properties such as triaxiality and failure strains should be specified in the LS-DYNA models as the current analysis do not appear to permit material failure/erosion, and thus potential part failure.

The design criteria (if any) used to design the package in the inelastic range and avoid exceeding uniform strains should be provided and/or clarified.

This information is needed by the staff to determine compliance with 10 CFR 71.33(a)(5).

Answer to 2.12

A summary of our stance on the treatment of material failure in the FEM model of the DN30 package is found below:

- the containment system of the DN30 package is provided by the 30B cylinder
- the DN30 PSP is not part of the containment system, it just provides mechanical and thermal protection for the 30B cylinder
- in the actual drop test program, local material failure of the DN30 PSP steel shell was observed for some drop orientations
- this had no adverse effect on the containment system (the 30B cylinder) and its leak-tightness
- the impact of local material failure on the LS-DYNA simulations was assessed by a sensitivity calculation where the cracks in the DN30 PSP shell that were observed in the drop tests were present in the FEM model before the 9m drop was performed
- in this simulation, the deformations have changed by less than 1 % compared to the unmodified FEM model
- in summary, there is no additional gain in confidence of the FEM analysis by introducing material damage or failure in the FEM model of the DN30 package

The details regarding the above-mentioned points are described in chapter 5 of Technical Note 0023-BBR-2019-004-Rev1. It is proven that the inelastic range is covered with the current stress-strain curves. In addition, it is shown that the simulation results are not sensitive to cracks in safety relevant areas. Hence, explicit simulation of material failure needs not be considered in the material modelling.

2.13 Describe the condition of the package after the compression test under normal conditions of transport.
This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(9).

Answer to 2.13

A quasi-static FEM analysis of the compression test has been performed and added to the SAR as Section 2.2.1.4.3. The results in this section prove that the DN30 package is in compliance with 10 CFR 71.71(c)(9) as only very local and very small plastic deformation (dents) below 5 % elongation occur at the outer shell that have no impact on any other safety feature of the DN30 PSP.

2.14 Provide measured data for the material properties used in the safety analyses or provide the basis and the justification for using estimated properties that were not based on testing.

The applicant provided both measured (from material testing conducted) and estimated (or assumed) values for material properties used in the safety analyses. The applicant should use measured material properties or provide a basis or a justification for all estimated material properties. The estimated material data include, but are not limited to:

- UF_6 properties: mechanical tests were performed using a solid block of iron concrete to simulate solid UF_6; thermal conductivity, specific heat capacity, and density were estimated.
- In Section 2.1.1.2 (30B cylinder) and Section 2.1.1.3 (DN30 PSP), staff notes that the material standard physical properties were estimated.
- Intumescent material: staff notes that chemistry information was not provided.

This information is needed to determine compliance with 10 CFR 71.43(d) and 71.43(f).

<u>Answer to 2.14</u>

For the model of the content UF_6, the following applies:

For the structural analysis, several drop tests were performed with a 30B cylinder filled with a solid block and debris on top of a mixture of concrete and steel grit representing the UF_6 content (which was not used itself for safety reasons). For the benchmarking of these sequences, and for the other sequences as well as, the softest concrete according to Eurocode 2 was used because the mechanical properties of UF_6 are unknown. This is also explained in answer to RAI 2.1.

For the thermal analysis, the fire tests were performed with an empty 30B cylinder. For the benchmarking, the properties of air were thus used. For the HAC calculation with a partially filled or filled 30B cylinder, the thermal properties of UF_6 were extracted from "Uranium Hexafluoride: a survey of the physico-chemical properties" by R. DeWitt from 1960. No concrete was used for the thermal analysis.

The intumescent material consists mainly of graphite which expands when exposed to heat.

2.15 Provide detailed thermal effects of the packaging materials on other functional (e.g., structural integrity) requirements.

The application did not provide detailed thermal effects of materials on all functional requirements of the package. The applicant needs to provide a basis and a justification for thermal effects: degradation of mechanical properties, degradation of integrity, alteration of materials, and thermal expansion.

The operating parameters and materials with incomplete thermal effects include, but are not limited to TFE (packing and pat cap gasket), EPDM (gasket), Polyamide (thermal plug), Polyester or Nylon (lifting sling), Florinate (lubricant), plug, valve and mantle, coating or paint for corrosion protection, seals, foam at a temperature above 250 °C.

This information is needed to determine compliance with 10 CFR 71.43(d) and 71.43(f).

Answer to 2.15

According to ANSI N14.1 or ISO 7195 the 30B cylinder is designed for a temperature range of -40 °C to 121 °C. For RCT and NCT, this covers:

- the general requirements towards materials of packagings to be adequate for a temperature range of -40 °C to +70 °C,
- the PTFE-based lubricants and the fluorinated lubricants as well as the plug, valve and mantle of the 30B cylinder,
- any paintings or coatings for protection against corrosion applied to the 30B cylinder.

After the valve has been closed, the PTFE-based and fluorinated lubricants are not relevant with regard to the leak-tightness of the 30B cylinder and, thus, are not relevant to fulfill any safety requirements of the DN30 package under HAC.

The temperature limit for the 30B cylinder under HAC is 131 °C. This is the lowest temperature that could pose a danger to the structural integrity of the 30B cylinder caused by elevated temperatures. The materials used for cylinder shell, valve and plug are according to ANSI N14.1:

- 30B cylinder shell: the maximum temperature defined in ASME BPVC for SA516 steel grade 55/60 is 371.11 °C or 700 °F
- valve/plug body (aluminum bronze UNS C63600): the melting point is 1030 °C, the hot-working temperature is 760 to 875 °C
- valve/plug stem (nickel copper alloy UNS N04400): the melting point is 1300 to 1350 °C, the hot-working temperature is 648 to 1176 °C
- valve/plug solder (tin-lead alloy): the solidus temperature of a tin lead solder compliant with ASTM B32 alloy grade Sn 50/50A is 183 °C, the liquidus temperature is 216 °C (see Attachment 4 of this document)

Therefore, the temperature limit of 183 °C is suitable for an empty 30B cylinder. However, for a filled or partially filled cylinder, a possible pressure build-up because of the solid-to-liquid phase change of UF_6 contents could pose a danger to the structural integrity of the 30B cylinder. A pressure build-up due to melted UF_6 contents is therefore investigated in the answer to RAI 3-6 for filling ratios of 0 to 100% with a maximum temperature of 131 °C. It is proven that the maximum pressure for a partially filled cylinder (50 %) is well below the test pressure (safety factor of 2.90 at a temperature of 131 °C) and below the test pressure for a filled cylinder (100 %) (safety factor of 1.07 at a temperature of 131 °C). Consequently, the pressure for an empty cylinder is even lower and all thermal effects have been considered for the 30B cylinder.

With a maximum temperature of 126 °C, the design temperature of 121 °C is only exceeded by 5 °C during HAC and the coatings can be expected to be still present after the fire test under HAC. Nevertheless, the coatings have no influence on the containment function of the 30B cylinder and, thus, they need not be considered in the safety analysis of the DN30 package under HAC.

For the DN30 PSP, all thermal effects have been considered as well - these are:

- Temperature dependent material properties for the drop tests under NCT and HAC
- Temperature dependent material properties for the thermal analysis:
    - The required temperature range of material properties for the thermal test is available for all materials except for the foam.
    - For the foam, the thermal conductivity and specific heat could not be measured above 250 °C.
    - To extend the available temperature range, these material properties are linearly extrapolated for temperatures above 250 °C.
    - The sensitivity of the simulation results with respect to the extrapolation is investigated in a sensitivity analysis (see Section 9.5 in Appendix 2.2.2.3 of the SAR for details).
    - In this sensitivity analysis, only the extrapolated values are varied by ±10 %. In addition, a set of parameters with the thermal conductivity and specific heat kept fixed above 250 °C is investigated.
    - The sensitivity analysis shows that the maximum temperatures are on a similar level (+3 % for +10 %, -3 % for -10 %) for the variation of the extrapolated thermal properties in the range of ±10 % and that the temperatures are 14 % lower if no extrapolation of the thermal properties is considered.
    - In addition, the extrapolation of these material properties is only relevant for temperatures up to approximately 300 °C. For temperatures above 300 °C, the foam is assumed to produce heat by burning/pyrolysis and the thermal properties become irrelevant.
- Thermal stresses because of differences in the thermal expansion coefficients (has been added in Section 2.2.1.6.1 in SAR Rev1, see also Answer 3.5).

- The gasket between the top and bottom half is not relevant with regards to the containment function of the 30B cylinder and, thus, is not relevant for the drop tests under NCT and HAC or for the thermal test under HAC.
- In the thermal test, the silicon pads will remain intact as the decomposition temperature of silicone is not reached (see Section 2.1.4.2.10 in the SAR).
- The thermal plugs are meant to melt during the thermal test under HAC to avoid any pressure development inside the DN30 PSP shells. During the fire, the melting temperature of the thermal plugs (100 °C) is exceeded by a large margin (outer shell temperature reaches almost 800 °C) so that melting of the plugs is guaranteed. The thermal plugs have proven their functionality during the experimental fire tests for HAC. Apart from melting during the fire test under HAC, no additional thermal effects of the thermal plugs are relevant for the safety analysis of the DN30 package.
- The thermal plugs are screwed into a cylindrical stainless-steel receptacle, which is welded to the outer shell. There is an EPDM gasket between the thermal plugs and receptacle to avoid water inleakage into the foam. Apart from this, the gasket has no other safety requirement and, thus, thermal effects need not be considered for the drop tests under NCT and HAC as well as the thermal test under HAC.
- The intumescent material is meant to expand when exposed to temperatures above 150 °C. This was proven in the fire tests for HAC. It has no other function.
- There are no coatings or paints for protection against corrosion applied to the DN30 PSP.

Apart from the thermal effects considered above, the following applies to the safety analysis of the DN30 package:

- There are no lifting slings attached to the package during transport.
- The high security-seals consist of steel and are not part of the package.

2.16 Provide a quantitative basis for the non-quantifiable terms frequently used to describe the material properties used in the safety analysis. Provide a justification that the qualitative basis used in the safety analysis is sufficient.
The applicant frequently used non-quantifiable terms to describe the safety basis for the materials properties used. The applicant needs to provide an adequate justification that qualitative bases are sufficient for the safety analyses.

Qualitative bases include, but are not limited to (i) "Significant" contribution from U-234 to heat generation, (ii) "Periodic" inspection in Section 1.8.2, with a frequency that is not provided, (iii) "no specifics" such as yield stress, fracture stress or ultimate stress, in mechanical properties, (iv) in Section 2.1.1.4, Table 14, the effect of content fracture on dose rate, the qualitative consequence with design modifications in Section 2.1.4, e.g., "considerable" or "negligible," "more robust,"; "much better" in thermal properties with silicon in Section 2.1.4.2.10.2, (v) "Small" deformation in Section 2.2.1.5.1.5.1.2.2; surface crack is not expected in Section 2.2.1.5.1.5.1.2.2., (vi) Measurement error in page 198, deceleration increases "slightly" in page 209, "excessive" coating degradation, etc.

This information is needed to determine compliance with 10 CFR 71.43(d) and 71.43(f).

<u>Answer to 2.16</u>

The SAR contains numerous tables with quantitative terms, such as e. g. deformations during drop tests and their comparison to variations of parameters for the simulation. In the tables the values are given, and the differences described in e. g. percentage. Whenever these differences were rather small with respect to the used analysis tool, the text describes the differences as small or negligible for better readability. E. g. a deviation between two analyses of less than 5 % could be considered as small, a difference of 1 % as negligible.

In detail:

In Section 1.3.5 of the SAR the contribution of the individual nuclides to the thermal power of content is evaluated in Table 3. This Table shows that 88 % of the thermal power results from the contribution of U-234. Hence it is fair to conclude that the significant contribution to the thermal power is from U-234.

Section 1.8.2 references ANSI N14.1 for the 30B cylinder and test instruction No. 0023-PA-2015-015. ANSI N14.1 specifies the frequency for 30B cylinders and test instruction No. 0023-PA-2015-015 specifies the frequency for the DN30 PSP (each with 5 years). This has been indicated in Section 1.8 (1.8.1 and 1.8.2).

It is not clear where "no specifics" is mentioned. Mechanical properties are given in the different tables in part 2 of the SAR (e. g. Table 10).

We do not understand the possible influence of content fracture on dose rates. The dose rate analysis has been carried out for a full cylinder, i.e. a cylinder "overfilled" completely with UF_6 and not for a cylinder filled with only 2 277 kg of UF_6. The influence of reduction of the fill amount has been shown as well. The max. dose rates occur for the theoretical case of an "overfilled" cylinder containing approx. 4 000 kg UF_6.

Section 2.1.4 is intended to provide an introduction into testing and design of the DN30 package. In order to provide a readable overview, such non-quantitative terms have been used.

Section 2.2.1.5.1.5.1.2.2 contains a Table specifying the values evaluated in the analysis, the text after the table is the interpretation of the values in the table and the assessment of the differences between -40 °C, RT and +60 °C. We think it is appropriate to emphasize our understanding of the calculated results by using the non-quantitative terms as used because this is common practice also to be found in other applications.

Measurement error on page 198: measurement of deformations of the specimens after the drop tests was quite complicated due to following facts:

- The outer or inner shell were heavily deformed by the impacts
- Due to the imprint of the target onto the specimen the precise start of deformation could not be located
- Secondary/tertiary impacts after the primary impact which could not be avoided in the real tests (the specimen showed a rebound and toppled over in some cases) lead to a masking of the exact primary deformation

In order to account for such issue resulting from real testing, the measurement error was discussed.

In any case, we have scanned the SAR for such qualitative wordings and replaced them with quantitative terms wherever possible. This has been listed in Attachment 9 of this document.

3 Thermal review

3.1 Provide deviations of the fire test conditions, from the fire test conditions required by 10 CFR 71, in Section 2.2.2.2.1.4, "Deviations of the test conditions from the test conditions required by [IAEA 2012]," of the application.

The applicant provided deviations of the fire test conditions from the test conditions required by IAEA 2012; however, the applicant did not provide the deviations of the test conditions from the test conditions required by 10 CFR 71.73(c)(4).

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Answer to 3.1

The test conditions required by 10 CFR 71 and IAEA 2012 are the same. Section 2.2.2.2.1.4 of the SAR has been updated to improve clarity and comprehensibility.

Below is an excerpt of the SAR with the revised section:

2.2.2.2.1.4 Test conditions of the thermal test compared to the test conditions required by [10CFR71] and [IAEA 2012]

The performance of the thermal test as required by [10CFR71] 71.73(c)(4) and [IAEA 2012] para. 728 is not feasible for the following reasons:

1. The thermal test cannot be performed with a kerosene fire but is carried out with a propane gas fire (environmental issues); this is allowed by [10CFR71] 71.73(c)(4) and [IAEA 2012] as it is shown in the SAR that the propane gas fire provided an equivalent total heat input to the package over a period of 30 minutes.
2. Several solar insolation cycles to reach a constant temperature pattern with the insolation defined in the Regulations cannot be reached under natural conditions; this was compensated by pre-heating the specimen up to 63 °C, which is higher than the temperature reached during several insolation cycles.
3. During the cooling phase, neither the solar insolation nor the ambient temperature of 38 °C can be reached under natural conditions; this condition is not specified in [10CFR71] 71.73(c)(4) but is allowed in [IAEA 2012] para. 728 to be corrected by analysis.

[…]

However, an important difference between a kerosene fire and a propane gas fire is the soot produced by the kerosene fire. This soot increases the surface absorptivity of the specimen considerably. [10CFR71] 71.73(c)(4) and [IAEA 2012] para. 728 require a coefficient not less than 0.8. Hence the outer surface of the DN30 prototypes was painted with a black coating satisfying this requirement (see Figure 110). The absorptivity of the black coating is certified to be higher than 0.8.

3.2 Provide justification that the emissivity and absorptivity values in Table 54, "Heat transfer by radiation at the surface of the DN30 package," meet the requirements of 10 CFR 71.73(c)(4).

Table 54 of the application presents the emissivity and absorptivity values used during the fire phase of the HAC analysis as 0.72. The application did discuss how the chosen value meets the required values in 10 CFR 71.73(c)(4). 10 CFR 71.73(c)(4) describes that, "Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, […]."

Title 10 of the Code of Federal Regulations (10 CFR) 71.73(c)(4) also describes that, "For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater."

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Answer to 3.2

The calculations for HAC were recalculated with a total radiation coefficient for the fire phase of 0.9 and the results listed in Section 2.2.2.3.5.1 have been updated accordingly. The requirements regarding emissivity and absorptivity coefficients listed in 10 CFR 71.73(c)(4) are met in the thermal calculations. Section 2.2.2.3.2.4.2 of the SAR and the corresponding table have been updated accordingly.

Below is an excerpt of the SAR with the revised section:

2.2.2.3.2.4.2 Radiation

The radiation coefficient of the outer surface of the DN30 package is 0.44 for RCT and NCT (stainless steel, rough surface). During the fire, the surface absorptivity is conservatively set to 1.0; the flame emissivity is set to 0.9 as required by [10CFR71] 71.73(c)(4) and [SSG-26] para. 728.28. The total radiation coefficient for the fire phase therefore is 0.9. In the cooling phase, the radiation coefficient is set to 0.8, as required by [10CFR71] 71.73(c)(4) and [SSG-26] para. 728.29 for soot covered surfaces. The radiation coefficients are listed in Table 56 below.

Table 56: Heat transfer by radiation at the surface of the DN30 package

RCT + NCT	Fire phase	Cooling down
Radiation coefficient [-]		
0.44	0.9	0.8

The maximum temperatures obtained from the recalculation are listed in the additional excerpt of the SAR below:

2.2.2.3.5.1 Temperatures at the DN30 package for full and partially filled 30B cylinders

This calculation repeats the benchmark calculation with the ambient temperatures defined in [10CFR71] or [IAEA 2012]. The deviations from the benchmark calculations are

• The fire temperature is set to 800 °C; the duration is 30 min.

• In the cooling phase the ambient temperature is 38 °C with solar insolation as defined in Table 54.

The maximum temperatures are listed in Table 61 below.

Table 61: Maximum temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder

Position	**Temperature [°C]**		
	Empty 30B cylinder	**Partially filled 30B cylinder (50 %)**	**Filled 30B cylinder (100 %)**
Valve	124	115	112
Plug	122	112	108
Mantle 30B cylinder	126	121	120
Inner shell DN30 PSP	191	191	191
Outer shell DN30 PSP	789	789	789

3.3 Provide justification for the convection equations in Section 2.2.2.3.2.4.3, “Convection,” of the application.

Section 2.2.2.3.2.4.3 of the application describes that, for the convective heat transfer for NCT as well as the post-fire phase of HAC, the formula Nu = 0.13*(Pr*Gr)1/3 is used. Also, Section 2.2.2.3.2.4.3 of the application describes that for the convective heat transfer for the fire phase of HAC, the equation Nu = 0.036*Pr1/3*Re0.8 from IAEA SSG-26, “Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition),” 728.31 is used.

From IAEA SSG-26 728.31, the convective heat transfer correlation for NCT is for vertical planes and has not been shown to be applicable to the DN30 PSP geometry. The convective heat transfer correlation for HAC has also not been justified to be applicable to the DN30 PSP geometry.

NUREG 1609, “Standard Review Plan for Transportation Packages for Radioactive Material,” describes in Section 3.5.3.1, “Evaluation by analysis,” staff should ensure that for each thermal analysis the appropriate expressions are used for conductive, convective, and radiative heat transfer among package components and from the surfaces of the package to the environment.

This information is needed to determine compliance with 10 CFR 71.71 and 71.73(c)(4).

Answer to 3.3

The convection equations in Section 2.2.2.3.2.4.3 were used to determine the convection coefficients used in the calculations. The calculation model was then benchmarked/modified using two real-world fire tests. The calculation model using these convection coefficients is in very good agreement with the real-world fire tests as demonstrated by both Benchmark fire tests and the corresponding Benchmark calculations. Furthermore, the heat transfer for HAC by convection is generally dominated by the heat transfer by radiation, especially for the fire phase.

A sensitivity analysis was conducted to further asses the influence of changes in the convective heat transfer. Therefore, additional calculations were conducted, where the convection coefficients (for NCT, the fire phase and cooling down) were increased or reduced by 10 % and 25 %, respectively. The resulting temperatures are listed in the table below:

Position	-25 %	-10 %	Standard	+10 %	+25 %
	max. Temperature [°C]				
Valve	123	122	122	122	122
Plug	121	121	121	120	120
Mantle 30B cylinder	125	125	125	124	124
Volume 30B cylinder	123	122	122	122	122
Inner shell DN30 PSP	188	188	188	188	188
Outer shell DN30 PSP	785	785	785	786	786

The sensitivity analysis shows that the heat transfer during HAC is dominated by radiation and that relatively large changes to the convection coefficients only lead to very small changes in the resulting temperatures of the package.

The convection coefficients used for the sensitivity analysis are listed below. The “Standard” value is used in the calculations for the SAR.

Convection coefficients for NCT and the HAC cooling phase:

Temperature [°C]	-25 %	-10 %	Standard	+10 %	+25 %
	Heat transfer coefficient [W/(m²·K)]				
38.1	0.47	0.62	0.69	0.76	0.78
39	1.01	1.35	1.50	1.65	1.69
40	1.28	1.70	1.89	2.08	2.13
50	2.26	3.02	3.35	3.69	3.77
60	2.71	3.62	4.02	4.42	4.52
70	3.01	4.01	4.46	4.91	5.02
80	3.23	4.31	4.79	5.27	5.39
90	3.40	4.54	5.04	5.54	5.67
100	3.54	4.72	5.24	5.76	5.90
150	3.95	5.27	5.85	6.44	6.58
200	4.14	5.52	6.13	6.74	6.90
250	4.23	5.63	6.26	6.89	7.04
300	4.26	5.68	6.31	6.94	7.10
350	4.27	5.69	6.32	6.95	7.11
400	4.26	5.68	6.31	6.94	7.10
450	4.24	5.65	6.28	6.91	7.07
500	4.21	5.62	6.24	6.86	7.02
550	4.22	5.63	6.25	6.88	7.03
600	4.15	5.54	6.15	6.77	6.92
650	4.11	5.48	6.09	6.70	6.85
700	4.08	5.44	6.04	6.64	6.80
750	4.04	5.39	5.99	6.59	6.74
800	4.00	5.34	5.93	6.52	6.67
850	3.97	5.29	5.88	6.47	6.62
900	3.94	5.25	5.83	6.41	6.56
950	3.89	5.19	5.77	6.35	6.49
1000	3.86	5.15	5.72	6.29	6.44

Convection coefficients for the HAC fire phase:

Temperature [°C]	**-25 %**	**-10 %**	**Standard**	**+10 %**	**+25 %**
	Heat transfer coefficient [W/(m²·K)]				
38.1	18.90	25.20	28.0	30.80	31.50
39	18.83	25.11	27.9	30.69	31.39
40	18.83	25.11	27.9	30.69	31.39
50	18.43	24.57	27.3	30.03	30.71
60	18.16	24.21	26.9	29.59	30.26
70	17.82	23.76	26.4	29.04	29.70
80	17.48	23.31	25.9	28.49	29.14
90	17.21	22.95	25.5	28.05	28.69
100	16.94	22.59	25.1	27.61	28.24
150	15.73	20.97	23.3	25.63	26.21
200	14.72	19.62	21.8	23.98	24.53
250	13.97	18.63	20.7	22.77	23.29
300	13.16	17.55	19.5	21.45	21.94
350	12.62	16.83	18.7	20.57	21.04
400	12.02	16.02	17.8	19.58	20.03
450	11.61	15.48	17.2	18.92	19.35
500	11.14	14.85	16.5	18.15	18.56
550	10.87	14.49	16.1	17.71	18.11
600	10.53	14.04	15.6	17.16	17.55
650	10.19	13.59	15.1	16.61	16.99
700	9.79	13.05	14.5	15.95	16.31
750	9.59	12.78	14.2	15.62	15.98
800	9.32	12.42	13.8	15.18	15.53
850	9.05	12.06	13.4	14.74	15.08
900	8.84	11.79	13.1	14.41	14.74
950	8.64	11.52	12.8	14.08	14.40
1000	8.44	11.25	12.5	13.75	14.06

3.4 Provide justification for the pool fire gas velocity in Section 2.2.2.3.2.4.3, “Convection,” of the application.

Section 2.2.2.3.2.4.3 of the application states that the pool fire gas velocity is assumed to be 7.5 m/s. No justification was provided for this value.

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Answer to 3.4

No pool fire gas velocities were recorded by BAM during the fire tests.

The calculation model was benchmarked using the convection coefficients calculated with a velocity of 7.5 m/s. They are in very good agreement with the real-world fire tests as demonstrated by both Benchmark fire tests and the corresponding Benchmark calculations. Furthermore, the heat transfer for HAC by convection is generally dominated by the heat transfer by radiation, especially for the fire phase, as demonstrated in the answer to RAI 3-3.

A sensitivity analysis was performed for the answer to RAI 3-3 for the convection coefficients. These calculations show for the fire phase that the influence of the heat transfer by convection for HAC is dominated by the heat transfer by radiation. Changes to the pool fire gas velocity and therefore to the convection coefficients lead to only very small differences in the maximum temperatures of the packages for HAC.

Additional literature was added for justification as well. Section 2.2.2.3.2.4.3 of the SAR has been updated to add the additional information.

Below is an excerpt of the SAR with the revised section:

2.2.2.3.2.4.3 Convection

[…]

The pool fire gas velocity is assumed with 7.5 m/s, based on recommendations given in [SSG-26] para. 728.30 and [PATRAM86]. The resulting convection coefficients are considerably higher than the coefficient of 10 W/(m·K) recommended in [SSG-26] para. 728.30 for large packages.

[…]

[PATRAM86] M.H. Burgess; Heat transfer boundary conditions in pool fires; PATRAM 1986

3.5 Provide evaluations of thermal stresses caused by constrained interfaces among package components resulting from temperature gradients and differential thermal expansion during normal conditions of transport (NCT) and hypothetical accident conditions (HAC).
The evaluations should include the maximum stresses as well as cyclic stresses during the service life of the package for NCT. For HAC, the maximum thermal stresses can occur either during or after the fire.

This information is needed to determine compliance with 10 CFR 71.71 and 71.73(c)(4).

Answer to 3.5

As explained in the answer to RAI 2.11, calculations for NCT were added to the SAR. They are listed in Section 2.2.1.6.

In this section, the stresses caused by temperature influences are investigated that might occur because of the expansion of the 30B cylinder inside the DN30 PSP or the expansion of the foam. In this regard, very conservative assumptions are used to bound the resulting stresses.

For NCT, it is shown that the gap between the 30B cylinder and the inner shells of the DN30 PSP is large enough to avoid any development of thermal stresses. In case of the foam expansion it was assumed that the steel parts do not extent at all and that all parts have the same temperature. However, the thermal analysis has shown that the average temperature of the foam parts is lower. Even with this assumption the calculated stress is only 39 MPa and thus significantly (by a factor of 5) below the yield strength. This means that such a pre-stressed DN30 PSP behaves slightly stiffer, which is covered by the simulations at room temperature and -40 °C.

For temperatures below room temperature, there are no thermal stresses.

Since the calculation of the thermal stresses is based on conservative assumptions, they can be expected to be lower than 39 MPa. Consequently, there is hardly any impact on the simulation results to be expected.

For HAC, no stresses are to be expected during or after the fire. During the first stages of the fire, the steel shells heat up faster than the foam, increasing the gap between both parts. With the incineration of the foam, the foam is reduced in volume and partly loses its structural integrity (see Figure 129 and Figure 130 of the SAR), so that no stresses are to be expected during cooling down.

Below is an excerpt of the SAR with the newly added section:

2.2.1.6 Additional proofs for the structural analysis

2.2.1.6.1 Stresses caused by temperature influences

Generally, there are only minor and negligible stresses caused by temperature influences for the following reasons:

- The DN30 PSP consists of a welded structure of austenitic stainless steel with the same thermal expansion coefficients in all parts.
- As there is only a very low thermal load from the content, the temperature differences from the heat produced by the content are negligible.
- The possibly different expansions of the top and bottom half of the DN30 PSP because of temperature differences caused by the different insolating conditions on the top and bottom half are small; the gaps between the flanges of the top and bottom half allow enough relative movement to compensate for the different expansions.
- The gaps between the DN30 PSP and the 30B cylinder are sufficient to compensate the different thermal expansions of the DN30 PSP and the 30B cylinder.

Nonetheless, possible stresses caused by the expansion of the 30B cylinder and the expansion of foam are investigated.

2.2.1.6.1.1 Stresses caused by expansion of the 30B cylinder

In case the DN30 PSP and the 30B cylinder are heated up simultaneously, no stresses can occur because the thermal expansion coefficient of the material of the 30B cylinder is smaller than that of the material of the DN30 PSP shells. The only situation, stresses due to thermal expansion might occur, is when the DN30 PSP cools down much faster than the 30B cylinder after heating. Hence, the following scenario is assumed for the proof:

- The DN30 PSP has a temperature of 100 °C (complying with the outer shell of the top half after 12 hours of solar insolation).
- The 30B cylinder has a temperature of 20 °C (complying with a 30B stored inside before loading).
- Under constant insolation, the 30B cylinder maximally heats up to 58 °C (see Table 60).
- Without insolation, the DN30 PSP cavity minimally cools down to 38 °C (see Table 60).

The length of the 30B cylinder according to [ANSI N14.1] and [ISO 7195] is 2070±13 mm. The minimal length of the cavity (bottom half) is $2084^{+4}_{+0}\ \mathrm{mm}$.

Then, the maximal expansion of the 30B cylinder is:

$$\Delta l_{\mathrm{Cyl}} = l_{\mathrm{Cyl,max}} \cdot \alpha_{T_{\mathrm{ref}}=20\,°\mathrm{C}} \cdot \Delta T = (2070\ \mathrm{mm} + 13\ \mathrm{mm}) \cdot \frac{11.5 \cdot 10^{-6}}{°\mathrm{C}} \cdot (58 - 20)\ °\mathrm{C} = 0.91\ \mathrm{mm}$$

For the DN30 PSP, the expansion after cooling down is independent of the maximal temperature reached during heating. This results in the following minimal expansion after cooling down:

$$\Delta l_{\mathrm{PSP}} = l_{\mathrm{PSP,min}} \cdot \alpha_{T_{\mathrm{ref}=20\,^{\circ}\mathrm{C}}} \cdot \Delta T = 2084\ \mathrm{mm} \cdot \frac{16.0 \cdot 10^{-6}}{^{\circ}\mathrm{C}} \cdot [100 - 20 - (100 - 38)]\ ^{\circ}\mathrm{C} = 0.6\ \mathrm{mm}$$

The total expansion difference is:

$$\Delta l = l_{\mathrm{PSP}} + \Delta l_{\mathrm{PSP}} - \left(l_{\mathrm{Cyl}} + \Delta l_{\mathrm{Cyl}}\right) = 2084\ \mathrm{mm} + 0.6\ \mathrm{mm} - (2083\ \mathrm{mm} + 0.91\ \mathrm{mm}) = 0.69\ \mathrm{mm}$$

Hence, the gap is wide enough to allow for the dimensional changes due to thermal differences.

2.2.1.6.1.2 Stresses caused by expansion of foam

The safety analysis for the DN30 package regarding the foam expansion due to heating is based on the following assumptions:

- The linear thermal expansion coefficient for all foam parts is assumed to be $\alpha_{\mathrm{foam}} = 45 \cdot 10^{-6}\ \mathrm{K}^{-1}$. This coefficient covers the values for RTS 120 and RTS 320 as documented in the manufacturer specifications (see Appendix 1.4.2 (Material Data PIR Foam)).
- Based on the foam flow curves determined in Appendix 2.2.1.3 (Structural Analysis of the DN30 package under NCT and HAC), the static elasticity modulus of the RTS 120 foam is $E_{\mathrm{foam}} = 170\ \mathrm{MPa}$.
- The entire DN30 PSP is assumed to be heated from 20 °C to a conservative temperature of 70 °C (63 °C were determined at the outer shell during RCT in Appendix 2.2.2.3 (Thermal Analysis), and the temperature of the other components was lower than 63 °C).
- A foam block with a cross section of $A_{\mathrm{foam}} = \frac{1}{2} \cdot \frac{\pi}{4} \cdot d_{\mathrm{shell}}^2$, that corresponds to the upper half of the DN30 package with a diameter $d_{\mathrm{shell}} = 1216\ \mathrm{mm}$ is enclosed in a steel shell with thickness $t_{\mathrm{shell}} = 3\ \mathrm{mm}$.
- The smallest cross section of the steel shell is calculated as: $A_{\mathrm{shell}} = \frac{d_{\mathrm{shell}}}{2} \cdot \pi \cdot t_{\mathrm{shell}}$

Due to the expansion of the foam by the thermal strain $\varepsilon_{\mathrm{therm}} = \alpha_{\mathrm{foam}} \cdot \Delta T$, a force acts on the steel shell. Without taking into account the expansion of the steel shell itself, the equilibrium of forces between the foam and the steel shell leads to the following stress in the steel shell:

$$F_{\mathrm{foam}} = \varepsilon_{\mathrm{therm}} \cdot E_{\mathrm{foam}} \cdot A_{\mathrm{foam}} = \sigma_{\mathrm{shell}} \cdot A_{\mathrm{shell}} = F_{\mathrm{shell}}$$

The stress in the outer shell of the DN30 PSP amounts to:

$$\sigma_{\mathrm{shell}} = \alpha_{\mathrm{foam}} \cdot \Delta T \cdot E_{\mathrm{foam}} \cdot \frac{A_{\mathrm{foam}}}{A_{\mathrm{shell}}} = 39\ \mathrm{MPa} < \mathrm{R}_{\mathrm{p},0,2} \text{ at } 70\ ^{\circ}\mathrm{C}$$

Even though very conservative assumptions were taken into account for the geometry of the foam block, the expansion of the steel shell and the expansion coefficient of the foam, the resulting stress in the steel shell reaches only about 22 % of its yield strength. Hence, only elastic deformations are to be expected and damaging of the package can be excluded.

2.2.1.6.1.3 Stresses caused by temperatures reached during HAC

For HAC, no stresses are to be expected during or after the fire. During the first stages of the fire, the steel shells heat up faster than the foam, increasing the gap between both parts. With the incineration of the foam, the foam is reduced in volume and partly loses its structural integrity (see Figure 129 and Figure 130), so that no stresses are to be expected during cooling down.

3.6 Provide justification for the 30B cylinder maximum admissible temperature limit for empty, partially full, and full 30B cylinders during HAC in comparison to the value in ANSI N14.1 and the UF_6 melting point. In addition, address the consequence of melted UF_6 contents.

Table 46, “Admissible component temperatures of the package DN30,” of the application states that the admissible temperature of the 30B cylinder shell is 400°C (752°F), and the valve and plug thread is 183°C (361°F) during HAC. ANSI N14.1, “American National Standard for Nuclear Materials - Uranium Hexafluoride – Packagings for Transport,” includes a design temperature of 250°F (121°C) (see Section 5.1.1, “Design Conditions,” Table 1, “UF_6 cylinder design conditions”). ANSI N14.1 is referenced in Section 1.3.1.3, “Permissible conditions for repeated use,” of the application.

The calculated temperatures of the 30B cylinder mantle (124°C) and valve (122°C) for an empty 30B cylinder in Table 58, “Maximum temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder,” of the application exceed the ANSI N14.1 maximum allowable temperature. The calculated temperatures of the partially filled 30B cylinder (50%) do not exceed 121°C. However, a lower fill percentage of a partially filled 30B cylinder may cause the 30B cylinder mantle or valve to exceed 121°C.

In addition, the melting point of UF_6 is 147°F (64°C), the calculated temperatures of the 30B cylinder, valve, and plug exceed the melting point of UF_6 in Table 58 of the application. The consequence, if any, of melted UF_6 contents during HAC has not been addressed in the application.

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Answer to 3.6

The section addressing the admissible temperatures for the DN30 package was reworked completely. For the admissible temperature of the 30B cylinder, the thermal properties of the materials (solidus/liquidus temperatures, maximum temperatures according to standards) were considered as well as a possible pressure build-up caused by melted UF_6 contents with regards to the UF_6 manual USEC 651 and the ASME BPVC.

Below is an excerpt of the SAR with the revised section:

2.2.2.1.4 Admissible component temperatures of the DN30 package

For the containment system of the DN30 package, which consists of the 30B cylinder with installed valve and plug as specified in [ANSI N14.1] and [ISO 7195], a covering admissible temperature is calculated that considers the admissible temperatures of the materials with regard to their thermal properties and with regard to a pressure build-up because of melted UF_6 contents according to [USEC 651] and [ASME BPVC].

The materials used for the cylinder shell, the valve and the plug are according to [ANSI N14.1]:

- 30B cylinder shell: the maximum temperature defined in [ASME BPVC] for SA516 steel grade 55/60 is 371.11 °C or 700 °F

- valve/plug body (aluminum bronze UNS C63600): the melting point is 1030 °C, the hot-working temperature is 760 to 875 °C
- valve/plug stem (nickel copper alloy UNS N04400): the melting point is 1300 to 1350 °C, the hot-working temperature is 648 to 1176 °C
- valve/plug solder (tin-lead alloy): the solidus temperature of a tin lead solder compliant with ASTM B32 alloy grade Sn 50/50A is 183 °C, the liquidus temperature is 216 °C

For temperatures above the triple point of UF_6 (64 °C) a pressure build-up is investigated for melted UF_6 contents. The following conservative assumptions are used for the calculations:

- The maximum temperature of the UF_6 is assumed to be the average temperature of all UF_6 in the 30B cylinder. Calculations show that only the outmost region of the UF6 in contact with the 30B cylinder shell will reach that maximum temperature while the core of the UF_6 is still in its solid state; the average temperature calculated for all UF_6 is well below that maximum temperature. For example, for the HAC calculation for a full cylinder (100 % filling), the maximum temperature of more than 50 % of all UF_6 in the 30B cylinder is still below the triple point of 64 °C.
- For the calculation of the pressure build-up, the pressure of the empty 30B cylinder is assumed to be 5 psi instead of 3 psi (cf. [USEC 651] sections 5.3.5 and 8.3).
- The calculations for the pressure build-up are calculated with the safe fill limit of 95 % instead of the minimum volume (cf. [USEC 651]).

The admissible pressure for the 30B cylinder, the valve and the plug for HAC is conservatively set to the test pressure of 2.76 MPa/400 psig as specified in [ANSI N14.1] for these components. The pressure build-up is investigated for filling ratios of 50 % and 100 % for a temperature of 131 °C/267.8 °F. The temperature of 131 °C was chosen as it is the maximum even Celsius temperature that still retains a safety margin of 1.05 for all investigated conditions.

The vapor pressure data of UF_6 is extracted from [WITT 1960] and listed in Table 45 below.

Table 45: Vapor pressure of UF_6 extracted from [WITT 1960]

Temperature [°C]	Vapor pressure [MPa]
63.88	0.1506 [1)]
64.20	0.1527
91.88	0.3395
99.94	0.4174
108.07	0.5091
116.03	0.6129
124.17	0.7349
133.19	0.8892
141.44	1.0517
149.50	1.2300
180.57	2.1313
207.32	3.2436
230.20	4.6103

[1)] vapor pressure of the solid, for all other temperatures: vapor pressure for the liquid

The calculation of the total pressure is based on [USEC 651]. The input data for a 30B cylinder is according to [ANSI N14.1]:

$V_{30B} = 26\ \mathrm{ft}^3$

$m_{\mathrm{UF6,max}} = 5020\ \mathrm{lb}$

$T_1 = 68\ °\mathrm{F}\ (20\ °\mathrm{C})$

$T_2 = 267.8\ °\mathrm{F}\ (131\ °\mathrm{C})$

$\rho_{\mathrm{UF6,1}} = 317.8\ ^{\mathrm{lb}}/_{\mathrm{ft}^3}$ (solid, at 20 °C/68 °F)

$\rho_{\mathrm{UF6,2}} = 198.6\ ^{\mathrm{lb}}/_{\mathrm{ft}^3}$ (liquid, at 131 °C/267.8 °F)

The pressure inside an empty 30B cylinder is 5 psi or less according to [USEC 651].

$p_{\mathrm{Air,0}} = 5\ \mathrm{psi}$

The volume of UF_6 and air inside the 30B cylinder for a filling ratio of 50 % are then:

$$V_{\mathrm{UF6,1}} = \frac{0.5 \cdot m_{\mathrm{UF6,max}}}{\rho_{\mathrm{UF6,1}}} = \frac{0.5 \cdot 5020\ \mathrm{lb}}{317.8\ ^{\mathrm{lb}}/_{\mathrm{ft}^3}} = 7.90\ \mathrm{ft}^3$$

$$\mathrm{V}_{\mathrm{Air,1}} = \mathrm{V}_{30\mathrm{B}} - \mathrm{V}_{\mathrm{UF6,1}} = 26\ \mathrm{ft}^3 - 7.90\ \mathrm{ft}^3 = 18.10\ \mathrm{ft}^3$$

The air pressure at 20 °C/68 °F is:

$$p_{\mathrm{Air},1} = \frac{p_{\mathrm{Air},0} \cdot V_{30\mathrm{B}}}{V_{\mathrm{Air},1}} = \frac{5\ \mathrm{psi} \cdot 26\ \mathrm{ft}^3}{18.10\ \mathrm{ft}^3} = 7.18\ \mathrm{psi}$$

The vapor pressure of liquid UF_6 at 131 °C/267.8 °F is interpolated linearly from Table 45:

$$p_{\mathrm{UF6},2} = 123.53\ \mathrm{psi}$$

The volume and pressure of the air inside the 30B cylinder at 131 °C/267.8 °F are:

$$V_{\mathrm{Air},2} = V_{30\mathrm{B}} - \frac{0.5 \cdot m_{\mathrm{UF6,max}}}{\rho_{\mathrm{UF6},2}} = 26\ \mathrm{ft}^3 - \frac{0.5 \cdot 5020\ \mathrm{lb}}{198.6\ \mathrm{lb}/\mathrm{ft}^3} = 13.36\ \mathrm{ft}^3$$

$$p_{\mathrm{Air},2} = p_{\mathrm{Air},1} \cdot \frac{V_{\mathrm{Air},1} \cdot T_2}{V_{\mathrm{Air},2} \cdot T_1} = 7.18\ \mathrm{psi} \cdot \frac{18.10\ \mathrm{ft}^3 \cdot 404.15\ \mathrm{K}}{13.36\ \mathrm{ft}^3 \cdot 293.15\ \mathrm{K}} = 13.42\ \mathrm{psi}$$

The total pressure at 131 °C/267.8 °F is the summation of the partial pressures:

$$p_{\mathrm{Total},2} = p_{\mathrm{UF6},2} + p_{\mathrm{Air},2} = 123.53\ \mathrm{psi} + 13.42\ \mathrm{psi} = 136.95\ \mathrm{psi} = 0.94\ \mathrm{MPa}$$

The admissible pressure for HAC is the test pressure specified in [ANSI N14.1], corrected for the elevated temperature of 131 °C/267.8 °F (above the design limit of 121 °C/250 °F). The strength values for ASME SA516 Grade 55 are according to [ASME BPVC]:

$$S_{\mathrm{u}}(200\ °\mathrm{F}) = S_{\mathrm{u}}(300\ °\mathrm{F}) = 55.0\ \mathrm{ksi}$$

$$S_{\mathrm{y}}(250\ °\mathrm{F}) = 27.0\ \mathrm{ksi}$$

$$S_{\mathrm{y}}(300\ °\mathrm{F}) = 26.5\ \mathrm{ksi}$$

The yield strength at 131 °C/267.8 °F is interpolated linearly:

$$S_{\mathrm{y}}(267.8\ °\mathrm{F}) = \frac{(267.8\ °\mathrm{F} - 250\ °\mathrm{F})}{(300\ °\mathrm{F} - 250\ °\mathrm{F})} \cdot (26.5\ \mathrm{ksi} - 27.0\ \mathrm{ksi}) + 27.0\ \mathrm{ksi} = 26.82\ \mathrm{ksi}$$

The corrected limit for an elevated temperature of 131 °C/267.8 °F is then:

$$p_{\mathrm{max},267.8\ °\mathrm{F}} = 400\ \mathrm{psi} \cdot \frac{26.82\ \mathrm{ksi}}{27.0\ \mathrm{ksi}} = 397.36\ \mathrm{psi} = 2.74\ \mathrm{MPa}$$

The maximum pressure at 131 °C/267.8 °F is below the corrected admissible pressure of 2.74 MPa/397.36 psi with a safety margin of 2.90 for a filling ratio of 50 %.

The volume of UF_6 and of the air inside the 30B cylinder for a filling ratio of 100 % are:

$$V_{\mathrm{UF6},1} = \frac{m_{\mathrm{UF6,max}}}{\rho_{\mathrm{UF6},1}} = \frac{5020\ \mathrm{lb}}{317.8\ \mathrm{lb}/\mathrm{ft}^3} = 15.80\ \mathrm{ft}^3$$

$$V_{\mathrm{Air},1} = V_{30\mathrm{B}} - V_{\mathrm{UF6},1} = 26\ \mathrm{ft}^3 - 15.80\ \mathrm{ft}^3 = 10.20\ \mathrm{ft}^3$$

The air pressure at 68 °F is:

$$p_{\mathrm{Air},1} = \frac{p_{\mathrm{Air},0} \cdot V_{30\mathrm{B}}}{V_{\mathrm{Air},1}} = \frac{5\ \mathrm{psi} \cdot 26\ \mathrm{ft}^3}{10.20\ \mathrm{ft}^3} = 12.74\ \mathrm{psi}$$

The vapor pressure of liquid UF_6 at 131 °C/267.8 °F is interpolated linearly from Table 45:

$$p_{\mathrm{UF6,2}} = 123.53\ \mathrm{psi}$$

The volume and pressure of the air inside the 30B cylinder at 131 °C/267.8 °F are:

$$V_{\mathrm{Air,2}} = V_{\mathrm{30B}} - \frac{m_{\mathrm{UF6,max}}}{\rho_{\mathrm{UF6,2}}} = 26\ \mathrm{ft}^3 - \frac{5020\ \mathrm{lb}}{198.6\ {}^{\mathrm{lb}}/_{\mathrm{ft}^3}} = 0.72\ \mathrm{ft}^3$$

$$p_{\mathrm{Air,2}} = p_{\mathrm{Air,1}} \cdot \frac{V_{\mathrm{Air,1}} \cdot T_2}{V_{\mathrm{Air,2}} \cdot T_1} = 12.74\ \mathrm{psi} \cdot \frac{10.20\ \mathrm{ft}^3 \cdot 404.15\ \mathrm{K}}{0.72\ \mathrm{ft}^3 \cdot 293.15\ \mathrm{K}} = 249.40\ \mathrm{psi}$$

The total pressure at 131 °C/267.8 °F is the summation of the partial pressures:

$$p_{\mathrm{Total,2}} = p_{\mathrm{UF6,2}} + p_{\mathrm{Air,2}} = 123.53\ \mathrm{psi} + 249.40\ \mathrm{psi} = 372.93\ \mathrm{psi} = 2.57\ \mathrm{MPa}$$

The maximum pressure at 131 °C/267.8 °F is below the corrected admissible pressure of 2.74 MPa/397.36 psi with a safety margin of 1.07 for a filling ratio of 100 %. As this safety is calculated with the testing pressure specified in [ANSI N14.1], this safety also includes an additional safety margin because the testing pressure only utilizes a maximum of 95 % of the yield strength for primary stresses (cf. [ASME BPVC]).

Additionally, the safety margin for the 30B cylinder is investigated according to ASME Code Section VIII – Division 1 for the maximum internal pressure of 2.57 MPa.

The dimensions of the 30B cylinder are according to [ANSI N14.1]:

Outer diameter:	$D_{\mathrm{o}} = 30\ \mathrm{in} = 762\ \mathrm{mm}$
Nominal shell thickness:	$t_{\mathrm{nom}} = {}^{1}/_{2}\ \mathrm{in} = 12.7\ \mathrm{mm}$
Minimum shell thickness:	$t_{\mathrm{min}} = {}^{5}/_{16}\ \mathrm{in} = 7.94\ \mathrm{mm}$
Joint efficiency:	$E = 0.85$ (spot RT as a minimum [ANSI N14.1])
Yield Strength at 131 °C	$S_{\mathrm{y,131\,°C}} = 26.8\ \mathrm{ksi} = 184.93\ \mathrm{MPa}$ (interpolated linearly from [ASME BPVC)

At first, the cylinder itself is investigated. The outside radius R_{o}, the inside diameter D and the inside radius R are calculated to:

$$R_{\mathrm{o}} = \frac{D_{\mathrm{o}}}{2} = \frac{762\ \mathrm{mm}}{2} = 381\ \mathrm{mm}$$

$$D = D_{\mathrm{o}} - 2 \cdot t_{\mathrm{min}} = 762\ \mathrm{mm} - 2 \cdot 7.94\ \mathrm{mm} = 746.1\ \mathrm{mm}$$

$$R = \frac{D}{2} = \frac{746.1\ \mathrm{mm}}{2} = 373.1\ \mathrm{mm}$$

The required wall thickness is then calculated according to the internal pressure design calculation of cylinders [ASME BPVC]. The formula and results are listed in Table 46

Table 46: Required wall thickness for the cylinder for internal pressure

	Paragraph/ Appendix	Formula	Required Wall Thickness t_{req}	Safety $S=t_{min}/t_{req}$
I	App. 1-1(1)	$t_{\text{req}} = \frac{p_{\max} \cdot R_{\text{o}}}{S_{\text{y}} \cdot E + 0.4 \cdot p_{\max}}$	6.06 mm	1.31
II	UG-27(1)	$t_{\text{req}} = \frac{p_{\max} \cdot R}{S_{\text{y}} \cdot E - 0.6 \cdot p_{\max}}$	6.16 mm	1.29
III	App. 1-2(1)	$t_{\text{req}} = R_{\text{o}}\left(1 - \exp\left(\frac{p_{\max}}{-S_{\text{y}} \cdot E}\right)\right)$	6.18 mm	1.28
IV	App. 1-2(1)	$t_{\text{req}} = R\left(\exp\left(\frac{p_{\max}}{S_{\text{y}} \cdot E}\right) - 1\right)$	6.15 mm	1.29

Next, the elliptical heads are investigated. The inside diameter D, the height h and the K-factor are:

$$D = D_{\text{o}} - 2 \cdot t_{min} = 762\text{ mm} - 2 \cdot 7.94\text{ mm} = 746.1\text{ mm}$$

$$h = \frac{D}{4} = \frac{746.1\,mm}{4} = 184.2\text{ mm}$$

$$K = \frac{1}{6} \cdot \left[2 + \left(\frac{D}{2 \cdot h}\right)^2\right] = \frac{1}{6} \cdot \left[2 + \left(\frac{746.1\,mm}{2 \cdot 184.2\,mm}\right)^2\right] = 1.02$$

The required wall thickness is calculated according to [ASME BPVC]. The results are listed in Table 47:

Table 47: Required wall thickness for the heads for internal pressure

	Paragraph/ Appendix	Formula	Required Wall Thickness t_{req}	Safety $S=t_{min}/t_{req}$
I	App. 1-4(1)	$t_{\text{req}} = \frac{p_{\max} \cdot D_{\text{o}} \cdot K}{2 \cdot S_{\text{y}} \cdot E + 2 \cdot p_{\max} \cdot (K - 0.1)}$	6.25 mm	1.27
II	App. 1-4(1)	$t_{\text{req}} = \frac{p_{\max} \cdot D \cdot K}{2 \cdot S_{\text{y}} \cdot E - 0.2 \cdot p_{\max}}$	6.22 mm	1.28

The minimum safety factors calculated according to [ASME BPVC] are 1.28 for the cylinder and 1.27 for the heads for a pressure of 2.57 MPa at a temperature of 131 °C/267.8 °F.

The admissible temperatures for the 30B cylinder, the valve and the plug are therefore set to 131 °C/267.8 °F. This admissible temperature is below the maximum temperatures, hot-working temperatures and liquidus temperatures/melting points of the used materials and there is no danger of rupture because of a possible pressure build-up caused by elevated temperatures and melted UF_6 contents.

The admissible component temperatures for the package DN30 are summarized in Table 48 for RCT, NCT and HAC.

Table 48: Admissible component temperatures of the package DN30

Component	Material	Admissible temperature [°C]		Remark / Reference
		RCT and NCT	HAC	
Outer shell of the DN30 PSP	Type 304/1.4301	70 / 100[1)]	900[6)]	70 °C for handling and RCT, 100 °C for the lifting lugs at the top half
Inner shell of the DN30 PSP	Type 304/1.4301	60[1)]	900[6)]	-
Foam insulation	PIR foam	60[2)]	-	Appendix 1.4.2 (Material Data PIR Foam)
Thermal insulation	MICROTHERM®	60[2)]	1000	Appendix 1.4.4 (Material Data Microtherm Overstitched 1000R HY)
Intumescent material	Promaseal	150[3)]	600	Appendix 1.4.3 (Material Data Intumescent Material)
30B cylinder shell	Pressure vessel steel	64[4)]	131[5)]	-
Valve and plug	Body: aluminum bronze Stem: nickel copper alloy Solder: tin lead alloy	64[4)]	131[5)]	-

1) calculation temperature

2) identical to temperature of shells

3) temperature where the expansion of the intumescent material starts

4) triple point temperature of UF_6

5) covering maximum temperature for the components of the 30B cylinder (see calculation above)

6) the hot forming of material Type 304/1.4301 is carried out at temperatures of 950 – 1200 °C. At 900 °C a sufficient strength remains, thus a deformation by own weight is not expected. The strength of the outer shell is neither relevant for the containment system nor for shielding and criticality safety.

3.7 Provide clarification to Section 2.2.2.3.4.2, “Results with solar insolation,” of the application regarding the maximum 30B temperature with constant insolation during NCT.

Section 2.2.2.3.4.2 of the application describes, “For the case of constant insolation over 24 hours with 100% of the insolation the maximum temperatures reached are 52°C for the 30B cylinder and its components. However, in Table 57, “Temperatures at the DN30 package loaded with a filled 30B cylinder under RCT and NCT,” the maximum temperature for the 30B cylinder and its components reaches 58°C with constant insolation over 24 hours.

This information is needed to determine compliance with 10 CFR 71.71.

Answer to 3.7

The discrepancy was resolved. The new table and text can be found in Section 2.2.2.3.4.2 of the SAR and in Answer 3.8 as well.

3.8 Provide a NCT thermal analysis of a DN30 package loaded with a partially filled 30B cylinder or provide justification that the thermal analysis during NCT with a filled 30B cylinder is the most limiting condition.

Table 57, "Temperatures at the DN30 package loaded with a filled 30B cylinder under RCT and NCT," of the application provides results with a filled 30B cylinder under NCT; however, Table 58, "Maximum temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder," of the application provides maximum temperatures with a partially filled, and filled 30B cylinder under HAC. Table 58 demonstrates that the highest temperatures are for a partially filled 30B cylinder, and the lowest temperatures are for a filled 30B cylinder.

This information is needed to determine compliance with 10 CFR 71.71.

Answer to 3.8

Additional calculations were performed for a partially filled cylinder (50 %) and an empty cylinder and added to the table. The calculations show that the temperatures at the 30B cylinder and its components are only marginally higher for the filled cylinder (100 %) for NCT than the temperatures for the partially filled (50 %) cylinder (T_{max} = 52.1 °C for filled and T_{max} = 52.0 °C for partially filled cylinder). These additional results have been listed in Section 2.2.2.3.4.2 of the SAR.

Below is an excerpt of the SAR with the revised section:

2.2.2.3.4.2 Results with solar insolation

The results for the cycle of 12 hours with insolation/ 12 hours without insolation according to [10CFR71] 71.71(c)(1) are shown in Table 60. The maximum temperature of 52 °C for a partially or completely filled 30B cylinder and for its components is reached after about 20 days. Hence, it can be assumed that the UF_6 remains solid under RCT and NCT conditions.

The maximum temperature of 63 °C complies with the initial conditions of the thermal test with a prototype.

Table 60: Temperatures at the DN30 package loaded with an empty, partially filled and filled 30B cylinder under RCT and NCT

Position	Temperature [°C]					
	Without insolation			12 hours insolation/ no insolation cycles		
	Empty 30B cylinder	Partially filled 30B cylinder (50 %)	Filled 30B cylinder (100 %)	Empty 30B cylinder	Partially filled 30B cylinder (50 %)	Filled 30B cylinder (100 %)
Valve	38	38	38	51	52	52
Plug	38	38	38	51	52	52
Mantle 30B cylinder	38	38	39	53	52	52
Volume 30B cylinder (UF_6/Air)	38	38	39	53	52	52
Inner shell DN30 PSP	38	38	38	56	56	56
Outer shell DN30 PSP	38	38	38	63	63	63

3.9 Provide confirmation that the maximum normal operating pressure (MNOP) during NCT has no effect on the DN30 PSP.

Section 2.2.2.4.1, "Ambient temperatures and pressures," of the application describes that, "Pressures which are likely to be encountered during RCT and NCT have no effect on the results of the thermal analysis." Section 1.2.8, "Maximum normal operating pressure," of the application states, "The maximum normal operating pressure for the DN30 package is defined as the pressure at the triple point of UF_6."; however, the applicant did not specify if the DN30 PSP is capable of maintaining a pressure during NCT, or if there is a design pressure limit for the DN30 PSP.

This information is needed to determine compliance with 10 CFR 71.71.

Answer to 3.9

The DN30 PSP is not capable of maintaining any pressure. Section 1.4.2.3.1 of the SAR has been updated accordingly.

Below is an excerpt of the SAR with the revised section:

1.4.2.3.1 Pressure envelope of the DN30 package

The 30B cylinder including its valve and plug is the pressure retaining component of the DN30 package.

The DN30 PSP is not designed as pressure retaining component. Due to its design, a pressure difference between the ambient and the DN30 PSP can be excluded.

For pressure release during HAC, the DN30 PSP is equipped with fusible plugs which will release any pressure induced by the decomposition of the foam parts.

3.10 Provide confirmation of the maximum allowable internal pressure of the 30B cylinder and address the discrepancy in maximum pressure during HAC.

The applicant described, in Section 2.2.1.5.3.1, “Internal pressure,” that the maximum allowable internal pressure of the 30B cylinder is 2.14 MPa (314 psig); however, Section 9.7, “Pressure build-up in the 30B cylinder,” of Appendix 2.2.2.3, “Thermal Analysis,” describes the maximum allowable internal pressure of 1.38 MPa that the 30B cylinder is designed for according to ANSI N14.1 and ISO 7195 and the temperature is only slightly above the maximum design temperature of 121°C (250°F).

The design pressure of the 30B cylinder is specified in ANSI N14.1, “American National Standard, for Nuclear Materials – Uranium Hexafluoride – Packagings for Transport,” which is equal to 200 psig (1.38 MPa) at 250 °F (121 °C).

In addition, the maximum pressure in Section 2.2.1.5.3.1, “Internal Pressure,” of the application is approximately 0.8 MPa during the thermal test; however, Section 2.2.2.4.2, “Rupture of the containment system,” of the application describes, “In Section 9.7 of Appendix 2.2.2.3 (Thermal Analysis) a maximum pressure of 0.75 MPa within the 30B cylinder during the thermal test (for a temperature of 125°C) is evaluated.”

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Answer to 3.10

The discrepancies were resolved. Both Sections 2.2.1.5.3.1 and 2.2.2.4.2 of the SAR have been updated accordingly.

Below is an excerpt of the SAR with the revised sections:

2.2.1.5.3.1 Internal pressure

The pressure build-up during the thermal test is investigated in Sections 2.2.2.1.4 and 2.2.2.3.5.2. The maximum pressure for the thermal test considering a pressure build-up caused by elevated temperatures and by melted UF_6 contents is below the admissible pressure. Damage of the 30B cylinder, valve or plug and, thus, an influence of the thermal test on the containment system of the DN30 package can be excluded.

[…]

2.2.2.4.2 Rupture of the containment system

A possible pressure build-up is investigated in Section 2.2.2.1.4 for the calculation of the admissible temperature of the containment system and in Section 2.2.2.3.5.2 for the maximum temperatures calculated for HAC. The maximum temperatures are below the admissible temperatures, the internal pressure is below the testing pressure specified in [ANSI N14.1] for the containment system and the wall thickness is above the required wall thickness calculated according to [ASME BPVC]. A possible pressure build-up due to melted UF_6 contents was taken into account. The requirements of [49CFR173] §173.420(a)(3) or [IAEA 2012] para. 632 c) are met.

3.11 Provide justification to show that the DN30 PSP components are not degraded at -40°C (-40°F).

The applicant specifie in Section 1.2.7, “Lowest Transport Temperature for which the Package is Designed,” of the application that the components were good to -40°C (-40°F). However, no justification was provided for that statement. The staff is specifically interested in any potential degradation of the polyisocyanurate rigid (PIR) foam, intumescent material Promaseal-PL®, and MICROTHERM®.

This information is needed to determine compliance with 10 CFR 71.71(c)(2).

Answer to 3.11

The 30B cylinder complies with the requirements of ANSI N14.1 and ISO 7195 in which a minimum transport temperature of -40 °C is specified.

The steel parts of the DN30 package except the 30B cylinder consist of austenitic stainless steel which is suitable for temperatures much lower than -40 °C.

Concerning the foam, polyisocyanurates are frequently used as supports in the cryogenic field due to their resistance to mechanical stress and insulating power. They are typically used in applications down to -200 °C. The material does not degrade at -40 °C.

The EPDM material of the gaskets of the DN30 PSP (the DN30 PSP has no containment function) is suitable for long term use down to -40 °C.

The polyamide plugs are as well suitable for long term use at -40 °C.

MICROTHERM® is used as insulating material for low and high temperature applications. It is suitable for the use down to -40 °C.

Promaseal-PL® consists mainly of Graphite and does not deteriorate at temperatures down to -40 °C. Its function is to foam up at temperatures around 150 °C.

4 Containment review

4.1 Provide details of the leakage rate tests in the Operations and Maintenance sections of the application.
Page 245/296 of 0023-BSH-2016-002-Rev0 indicated that the containment would have a design standard leakage rate of 1E-4 Pa m^3/sec. However, there was no discussion as to the type of leakage rate test (e.g., fabrication, pre-shipment), test methodology, standard for performing the test, or qualifications for those performing the test.

This information is needed to determine compliance with 10 CFR 71.37(b), and 71.43(f).

Answer to 4.1

The containment of the DN30 package is the 30B cylinder. This cylinder is specified in ANSI N14.1 and ISO 7195. The leakage rate specified in these documents to be tested after manufacturing and during each recertification is equivalent to the design standard leakage rate of the DN30 package.

The leakage rate is verified before each transport. As stated in our answer to RAI 1.1, we have updated section 1.7 of the SAR.

4.2 Clarify in the application the leakage test methodology (e.g., pulling vacuum with helium inside 30B cylinder), the leakage rate of the 30B cylinder prior to physical testing (if performed), and the extent of the 30B cylinder (e.g., welds, valve, plug) that was leakage tested after the six drop and thermal tests.

Details associated with the leakage rate tests after the hypothetical accident condition test were not discussed; for example, it was not clear which components (e.g., valve, plug, welds) were leak tested after the hypothetical accident condition test. This information is needed to understand the relevance of the leakage rate test results.

This information is needed to determine compliance with 10 CFR 71.37(b), and 71.43(f).

Answer to 4.2

Section 2.1.3.3 has been divided into two Sections: 2.1.3.3.1 containing the already present information about the containment design analysis, and 2.1.3.3.2 (new) describing the test methodology of the leakage tests carried out before and after each of the drop test sequences and the fire tests.

Below is an excerpt of the SAR with the newly added section:

2.1.3.3.2 Leakage test method and results for the drop and fire tests

Before and after each drop test sequence and before and after each fire test the leakage rate of the dummy cylinders used for the tests as part of the DN30 prototypes was measured.

Standard 30B cylinders according to ANSI N14.1 and ISO 7195 were modified for this purpose: on the side of the valve, at the 180° position relative to the valve, a third orifice was added, through which the cylinder was evacuated (see Figure below).

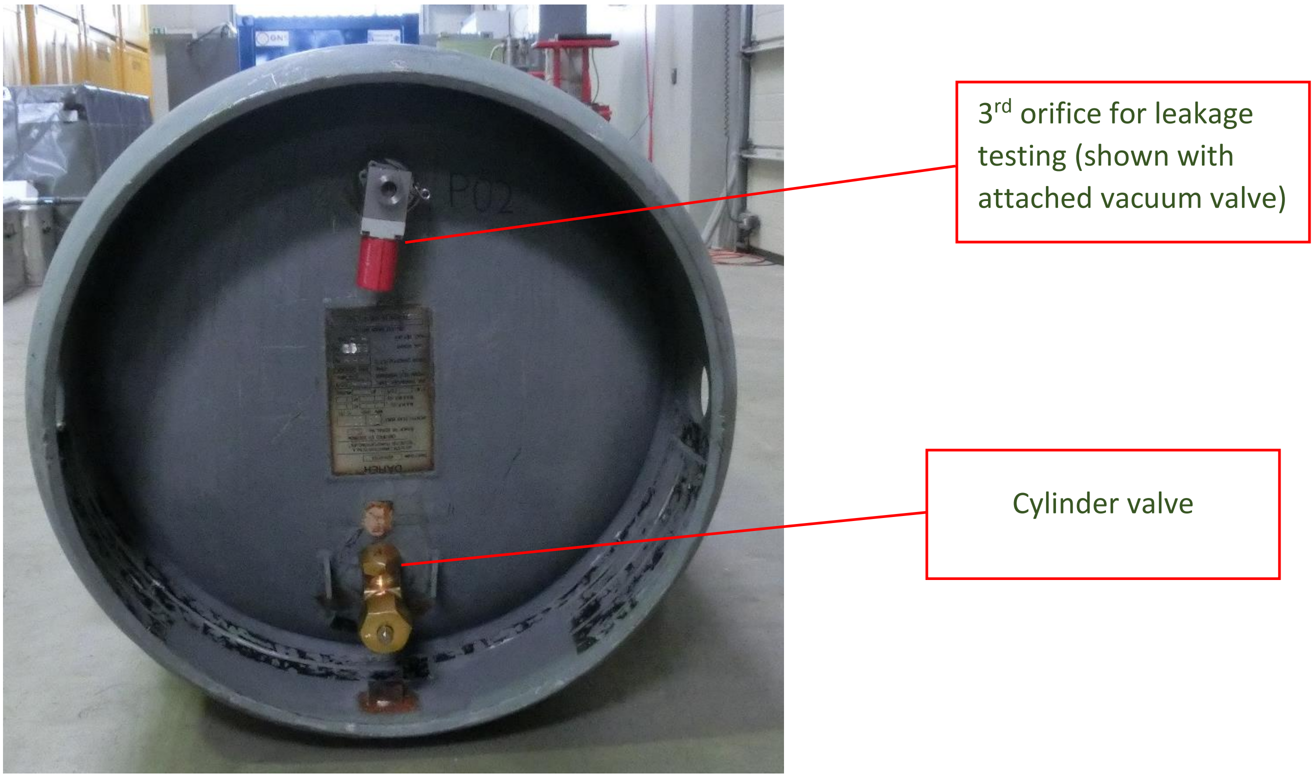


Figure: Example of a dummy cylinder used during the drop tests and fire tests for the testing of the leakage rate (valve side, upside down)

This orifice is connected to the vacuum pump (see Figure below).

Figure: Mounting of the vacuum pump

After establishing a sufficiently low pressure in the cylinder to operate the Helium leak detector, the pump is detached and the Helium leak detector is attached to the orifice. The complete cylinder is then placed in a box to establish the Helium space (Helium cage). After that, the leakage measurements are carried out:

1. Measure the Helium background level
2. Measure the Helium leakage rate of a specified test leak to ensure proper functioning of the equipment
3. Insert Helium into the Helium cage to envelope the complete cylinder
4. Measure the Helium leakage rate without and with test leak to verify the results

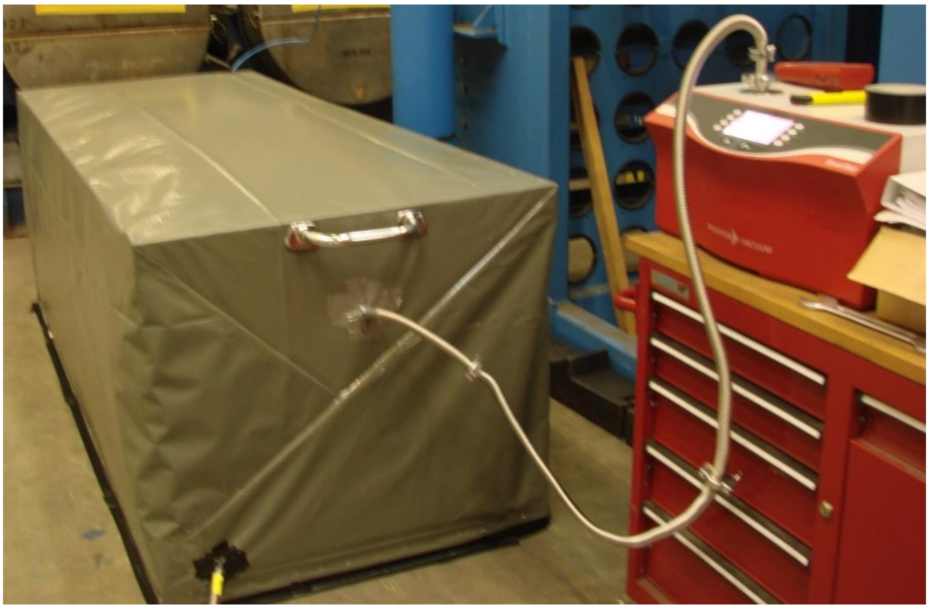


Figure: Helium cage around the cylinder

This test method provides reliable results for the integral Helium leakage rate.

The Table below recaps the leakage rate before and after the drop tests and the fire test.

Table: Leak rates before and after each test

Type of test	Leak rate before the test ($Pa.m^3/s$)	Leak rate after the test ($Pa.m^3/s$)
Drop sequence 1	5.67×10^{-8}	4.94×10^{-9}
Drop sequence 2	7.20×10^{-8}	4.15×10^{-6} *1)*
Drop sequence 3	2.86×10^{-8}	3.19×10^{-8}
Drop sequence 4	3.57×10^{-8}	7.09×10^{-8}
Drop sequence 5	5.08×10^{-8}	1.37×10^{-8}
Fire benchmark 1	6.58×10^{-8}	6.63×10^{-9}

1) Test was cancelled due to high He underground in the equipment

6 Criticality review

6.1 Provide the references cited in Section 6.3.1 of Appendix 2.2.5, Rev.1 regarding hydrogenated uranium residues.

The applicant refers to references [MILIN 2016], [CONNOR 2013], [BEGUE 2013], and [REZGUI 2013] as part of their discussion regarding the amount of moderator present in the DN30 package. Notably, the H/U ratio of 11 appears to be higher than what is typically used in other UF_6 analyses performed by the NRC, since the transportable form of UF_6 is typically a solid and have H/U ratios lower than 0.1.

Also, the statement in Section 6.3.2, near the bottom of Page 23 of the appendix, indicated that these studies are “very contradictory”. Staff needs to review these references to determine if they are reasonable assumptions to use to determine the subcriticality of the DN30 transport package.

This information is needed to determine compliance with 10 CFR 71.71 and 71.73.

Answer to 6.1

The references cited in Section 6.3.1 of Appendix 2.2.5, Rev.1 are appended to this document (Attachments 5, 6, 7 and 8). They all investigate the possible compositions and the potential amount of hydrogenated uranium residues (HUR) that are a potential part of the 0.5 wt.% impurities in the UF_6. For these impurities only, the H/U ratio can be as high as 11, as is explained in Section 6.3.2. The mean H/U ratio of the UF_6 content when taking these impurities into account will be lower than 0.1.

Please note that the statement about “very contradictory” studies in Section 6.3.2 does not refer to the references in Section 6.3.1, but rather to the studies about the possible composition of hydrates of uranyl fluoride that are cited near the bottom of Page 23 and the top of Page 24 ([LY-MI 1990], [TS-SE-SU 1972], [NEVEU 1961], [BR-GA-WH 1959] and [M-F-D-F 1998]). The various predictions from these references about the hydrate compositions are conservatively covered in our criticality analysis by assuming $UO_2F_2*4H_2O*3HF$ with the high H/U ratio of 11.

For further clarification, the rest of Section 6.3.2 determines the maximal potential amount of this HUR material based on 19 fillings of the cylinder and the covering assumption that all HUR that is formed due to the interaction of HF impurities with water vapor in the air during the filling will accumulate in the 30B cylinder (i.e. neither decompose nor be flushed out when the cylinder is emptied before the next filling).

The conservative assumption of 100 % humidity results in 2.022 mol H_2O in an air-filled empty 30B cylinder. All of this is assumed to create $UO_2F_2*4H_2O*3HF$, which means that 2.022 / 4 mol or 0.5055 mol of this HUR material will be formed. With 19 fillings over a 5-year period, this results in the 9.6045 mol given in Section 6.3.2.

6.2 Provide additional justification for the amount of water ingress calculated in Section 6.7 of Appendix 2.2.5, Rev.1 and the applicability of these calculations to Section 10.2.1 of the appendix.

The applicant's discussion in Section 6.7 indicated a very small quantity of water ingress (i.e., 2.55 grams) when the DN30 package is assumed to be submerged under HAC. For UF_6 packages, the size of a cylinder breach is the primary determining factor for water ingress. For small in-leakages of water, cylinders tend to be self-sealing by uranic breakdown products, however, for larger in-leakages of water, this may not be true.

It is unclear to staff exactly how this value of water ingress is used in the criticality safety analysis. Moderation levels within the DN30 package are of concern regarding the subcriticality of this package under HAC, where a larger breach in the cylinder may be possible.

This information is needed to determine compliance with 10 CFR 71.55(b)(2), 71.55(g), and 71.73(a)(5).

<u>Answer to 6.2</u>

The safety analysis for the DN30 package demonstrates that larger breaches of the 30B cylinder under HAC are not possible. For package prototypes that were subjected to the HAC tests described in 10 CFR 71.73(a), it was proven that there is no increase of the standard Helium leakage rates after tests (see Table 62 on Page 246 of the SAR).

Accordingly, the standard leakage rate of 10^{-4} Pa·m³/s for 30B cylinders given in ANSI N14.1 or ISO 7195 is an applicable and covering basis for the determination of possible water ingress in Section 6.7 of Appendix 2.2.5, Rev.1. Please also note that the calculation in Section 6.7 is not based on the water depth of 0.9 m intended to determine water ingress for criticality safety from 10 CFR 71.73(c)(5) but rather on the more penalizing water depth of 15 m from 10 CFR 71.73(c)(6).

While the calculation in Section 6.7 references ISO 12807 for the determination of gas and liquid leakage rates, the formulas are equivalent to those given in ANSI N14.5 except for the units. The result from the analysis is an amount of water ingress of < 3 g. As stated at the end of Section 6.7 and in Section 10.2.1 of the Appendix, this is negligible compared to the hydrogeneous impurities of 11385 g HF and 3908.3 g UO_2F_2*5.5H_2O considered throughout the criticality analysis, and was, accordingly, not further taken into account.

In Sections 1.5.3, 1.6.6 and 2.2.5.2.2 of the SAR, this maximal amount of 3 g water ingress has been added for clarification.

6.3 Provide additional justification that the validation cases used for the DN30 transportation package are adequate for the proposed contents.

The validation cases used by the applicant in Section 5.2 of Appendix 2.2.5, Rev. 1 of the SAR are drawn from a single benchmark set, LEU-COMP-THERM-033, which includes enrichments between 2 and 3 wt% 235U. There is no discussion of trends in the bias or extrapolation to the maximum enrichment of 5 wt% as requested by the applicant.

This level of extrapolation is well beyond what is provided by the experimental data, exceeds the commonly accepted guidelines of ISG-21, and does not address what is outlined as adequate in NUREG/CR-6361, NUREG/CR-6698, and ANSI/ANS-8.24-2017. The validation should consider the linear trend in the bias and the uncertainties in the bias.

This information is needed to determine compliance with 10 CFR 71.31(a)(2) and 71.35(a).

Answer to 6.3

The validation for the DN30 criticality safety analysis was extended with more uranium fluoride compound benchmark experiments. This extended validation is documented in detail in Technical Note 0023-BBR-2019-003-Rev0 (Attachment 2 to this document), but the central results are summarized below.

Trending of the k_{eff} results with the ^{235}U enrichment and the energy of the average lethargy of fission is used to demonstrate the applicability of the benchmark series LCT-033. A new determination of the calculation bias that takes the bias uncertainty into account results in a bias of $\Delta k = 0.0129$ instead of $\Delta k = 0$.

The calculation result for the covering criticality calculation model for the DN30 package, described in Section 2.2.5.5.3.3 of the DN30 SAR and, in more detail, in Section 9.8.7 of Appendix 2.2.5, shows that the DN30 package will still comply with the criticality safety criterion:

$k_{eff} + 3\sigma + \Delta k = 0.9351 + 0.0129 = 0.9480 \leq 0.95$

Furthermore, a brief sensitivity study where the remaining thickness of the DN30 PSP is assumed to be larger than a single compressed steel layer of 5 mm after HAC is performed. The results illustrate the large subcriticality safety margins for still conservative, but more realistic assumptions about the deformations of the DN30.

For an infinite array of bare 30B cylinders, the safety criterion is slightly exceeded, but since this result mainly has an illustrative purpose, this has no impact on the safety assessment of the DN30 package. The definition of the confinement system in chapter 1.4.5 of the SAR and the description of the assumptions of the criticality safety analysis in chapter 1.5.3.3 will be updated accordingly.

Chapter 2.2.5 of the SAR will be updated with the Δk value from the new validation and a reference to Technical Note 0023-BBR-2019-003-Rev0.

6.4 Provide additional justification for assuming at least 20 cm of water reflection for a single DN30 transportation package in isolation.
Section 7 of Appendix 2.2.5, Rev.1 states that at least 20 cm of water reflection is used for all calculation models in accordance with [ADR 2017] Section 6.4.11.9 and [IAEA 2012] para. 681. The typical practice for transportation packages is to assume 12 inches (30 cm) for full water reflection.

Although the reactivity difference may not be significant, given that some of the cases evaluated by the applicant approach the k_{eff} limit of 0.95, assuming less than full water reflection may not provide an adequate safety margin given the above information requested regarding code validation.

This information is needed to determine compliance with 10 CFR 71.55(e)(3).

Answer to 6.4

It should be noted that k_{eff} results close to the limit of safe subcriticality of 0.95 only occur for calculations with infinite package arrays. The calculation results for a single package in isolation, presented in detail in Section 8 of Appendix 2.2.5, Rev.1 and summarized in Section 10 of the Appendix and Section 2.2.5.5.1 of the SAR, demonstrate a maximal k_{eff} result for the single package of less than 0.62.

Furthermore, experience shows that full reflection for thermal systems is already achieved with a 20 cm water reflector; increasing the reflector thickness to 30 cm will usually only make a difference for systems with a fast neutron spectrum. This is corroborated by the results from a short sensitivity study with increased water reflector thickness for the covering geometries for the single package under NCT and HAC shown in the table below: the calculation results with reflector thicknesses of 20 cm, 25 cm and 30 cm agree within the statistical uncertainty.

covering geometry for RCT and NCT (SAR Section 2.2.5.5.1.3)		
water reflector	**k_{eff}**	**σ**
20 cm	0.5701	0.0011
25 cm	0.5670	0.0011
30 cm	0.5686	0.0011

covering geometry for HAC (SAR Section 2.2.5.5.1.4)		
water reflector	**k_{eff}**	**σ**
20 cm	0.6069	0.0010
25 cm	0.6049	0.0010
30 cm	0.6046	0.0011

6.5 Clarify the most reactive UF_6 fill levels in the DN30 transportation package.
Section 7.3.1 of Appendix 2.5.5, Rev.1 states that a completely filled 30B cylinder (i.e., 60.7%) is more reactive than a partially filled cylinder. Contrary to that statement, the calculation model in Section 7.3.2 indicates that the FILL2 configuration is more reactive than a completely filled cylinder, even though the quantity of UF_6 is less than the maximum allowable mass of 2277 kg of UF_6.

This information is needed to determine compliance with 10 CFR 71.55(e)(1).

Answer to 6.5

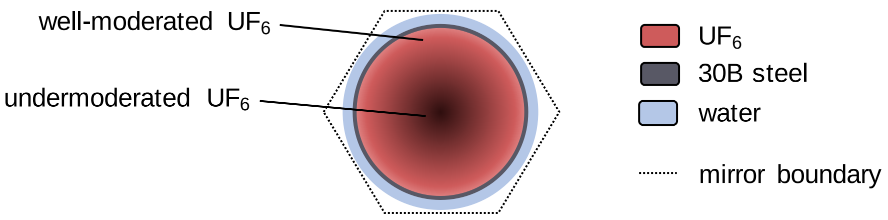
The statements about the most reactive UF_6 fill level in Sections 7.3.1 and 7.3.2 of Appendix 2.2.5, Rev.1 refer to different assumptions about the geometry of the UF_6 within the 30B cylinder, so there is no contradiction. Moreover, 'completely filled' here actually does not refer to a cylinder filled up to the limit of 60.7 %, but to a cylinder filled to 100 % with UF_6. This obviously overestimates the amount of fissile material that can be present in an actual DN30 package. Furthermore, all UF_6 filling states between 0 and 100 % are examined, so that there are no restrictions on the fill levels from the criticality safety analysis.

Since the statements about the optimal fill level are rather brief, some additional explanation will help to clarify: for the UF_6 geometry described in Section 7.3.1, called FILL1, the UF_6 is located in the lower part of the 30B cylinder, with a level surface between the UF_6 below and the empty cavity above. This level surface simply rises upwards as the fill level increases. For this geometry FILL1, the covering scenario is indeed a completely filled cylinder, as the calculation results in Section 8.5 for a single package and in Section 9.4 for an infinite package array show.

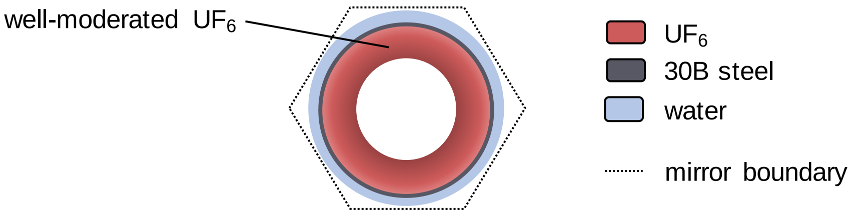
For the UF_6 geometry described in Section 7.3.2, called FILL2, the UF_6 is attached to the inner walls of the 30B cylinder, with a cylindrical empty space in the center for fill levels below 100 %. For this geometry FILL2, a completely filled cylinder is still the covering scenario for a single package in isolation, as the results in Section 8.6 show.

However, for an infinite package array with optimal moderation in the interstitial region between packages, lower fill grades can lead to the highest k_{eff} results (see Section 9.5). In this configuration, the fissions mostly occur in the well-moderated UF_6 region in close proximity to adjacent cylinders, meaning close to the inner cylinder wall. In completely filled cylinders, UF_6 located in the cylinder center is undermoderated and thus will not contribute a lot of fissions. It will, however, lead to absorption of some neutrons in the ^{238}U content, thus decreasing reactivity.

Removing part of the undermoderated UF_6 from the center, i.e. going to fill grades below 100 %, increases the neutronic coupling between the optimally moderated UF_6 regions adjacent to the cylinder walls (see figure below) and will therefore increase the reactivity.



completely filled 30B cylinders
(cut of the calculation model)



partially filled 30B cylinders
(cut of the calculation model)

7 Operating procedures

7.1 Provide non-proprietary appendices for the DN-30 package handling instruction and test instructions.
The following appendices have been submitted as proprietary:

- “Handling Instruction No. 0023-HA-2015-001-Rev 2,”
- “Periodical Inspections of DN30 PSP, Test Instruction 0023-PA-2015-015-Rev 1,” and,
- “Inspection Criteria and Maintenance of the DN30 PSP, Test Instruction, 0023-PA-2015-016-Rev 1.

These documents include procedures, tests, and maintenance programs that are described in Chapter 7, “Operating Procedure Review,” and Chapter 8, “Acceptance Tests and Maintenance Program Review,” of NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material.” This information is a requirement in a Certificate of Compliance and, therefore, should not be proprietary.

This information is needed to determine compliance with 10 CFR 71.31(c), 71.35(c), 71.37(b), 71.87, 71.89.

Answer to 7.1

The three appendices have been changed to non-proprietary as indicated in the corresponding pages of the main SAR.

7.2 Clarify that as part of the DN-30 inspections prior to each use, items inspected will be replaced if inspection shows excessive wear or any defects.
Step L.8 “Inspections” on page 17/33 of 0023-HA-2015-001-Rev2 indicates that an inspection will “check the presence” of the DN-30 gasket (top half), thermal plugs, pads, etc. However, the explanation should specify that these items will be replaced if the inspection shows excessive wear and defects.

This information is needed to determine compliance with 10 CFR 71.41, 71.87(b).

Answer to 7.2

Handling Instruction No. 0023-HA-2015-001 has been updated to prescribe the replacement of the items specified in step L.8 before loading a 30B cylinder, if the visual inspection shows excessive wear and/or defects.

7.3 Provide detailed procedures/operations to ensure there is no air (with moisture)/water exchange with the 30B cylinder (e.g., vessel, valve or plug).
The application includes statements regarding the potential formation of fluorides and other uranium compounds. If leak-tightness is not ensured, moisture or water may intrude continuously and thus react with fissile materials, corrode steel, or form deposits.

This information is needed to determine compliance with 10 CFR 71.43(d) and 71.43(f).

Answer to 7.3

The 30B cylinder is the containment of the DN30 package. It is designed and recertified according to ANSI N14.1 and ISO 7195. The leakage rate is 10^{-4} Pa m^3/s as specified in these standards. As answered to RAI 1.1 the tests before each transport ensure that the cylinder, i.e. the containment of the DN30 package has a leakage rate of less than or equal to 10^{-4} Pa m^3/s.

During transport there is neither air exchange nor any water exchange between ambient and cylinder cavity.

For criticality safety analysis hypothetical assumptions have been made to establish a conservative case. These assumptions include among others that prior to filling the empty cylinder contains air with 100 % humidity which reacts with the UF_6 to so called HUR. This assumption is highly hypothetical and applies to the criticality safety analysis only. Free water inside the cylinder can be excluded as any moisture reacts immediately with UF_6.

Criticality safety has been shown with the accumulation of HUR from multiple fillings of the cylinder, see answer to RAI 6.2.

List of attachments

Attachment 1: Technical Note 0023-BBR-2019-004-Rev1

Attachment 2: Technical Note 0023-BBR-2019-003-Rev0

Attachment 3: Nord-Lock washers guidelines

Attachment 4: Technical information sheet 50/50 tin lead solder

Attachment 5: [MILIN 2016]

Attachment 6: [CONNOR 2013]

Attachment 7: [BEGUE 2013]

Attachment 8: [REZGUI 2013]

Attachment 9: List of replaced qualitative into quantitative wording from SAR