Request for Additional Information
Docket No. 71-3088
Model No. CASTOR THTR/AVR Package

By letter dated March 11, 2015, the Department of Transportation submitted a request for review of the German Certificate of Approval No. D/4214/B(U)F-96 (Rev. 10) for the CASTOR THTR/AVR package and make a recommendation concerning the revalidation of the package for import and export use

This request for additional information (RAI) identifies information needed by the U.S. Nuclear Regulatory Commission staff in connection with its review of the Model No. CASTOR THTR/AVR package to determine whether the applicant has demonstrated compliance with the International Atomic Energy Agency, "Regulations for the Safe Transport of Radioactive Material," TS-R-1, 2009 Edition.

II Structural and Materials Evaluation

2.1 Provide the following reference, used in the design of the trunnions, to determine the adequacy of the prescribed amount of bolt torque:

MV 33 GNB Montagevorschrift für den Transport- und Lagerbehälter CASTOR® THTR/AVR *Assembling Rules for Transport and Storage Casks CASTOR® THTR/AVR*. Include MV 33, Rev. 0 and MV 33, Rev. 3, if different from the reference mentioned above.

This information is required by the staff to determine compliance with paragraph 607 of IAEA TS-R-1.

2.2 Clarify the use of material DIN 1705 for the construction of the trunnions.

Pages 22 and 35 of document GNB B 081/2000 E indicate that material values conforming to DIN 1705 are being used for the construction of the trunnions. However, this material does not appear to be referenced in the plans or elsewhere in the calculations.

This information is required by the staff to determine compliance with paragraph 607 of IAEA TS-R-1.

2.3 Justify the moduli of elasticity used in determining the contact stresses between the trunnion and the ductile cast iron shell.

Table 10, on page 35, of the document GNB B 081/2000 E, indicates that a modulus of elasticity of 100,000 MPa is used for the ductile cast iron, instead of 163,500 MPa, with regard to the contact stress calculations between the trunnion and the ductile cast iron shell. This results in a contact stress of up to 258 MPa, which is under the limit of 270 MPa. However, this limit appears to be exceeded when the modulus of elasticity for ductile cast iron, i.e., 163,500 MPa, is used.

This information is required by the staff to determine compliance with paragraph 607 of IAEA TS-R-1.

2.4 Justify the calculated overstress observed in the trunnion bolts for the M24 bolts torqued to 470 Nm.

Page 26 of 55 of document GNB B 081/2000 E indicates that an overstress of 103% is observed for trunnion bolts where KTA 3905 requirements do not apply. Page 11 of 55 indicates that settlement of the connection will occur, and stress will decrease below 100% of the allowable yield. However, if settlement of the connection is allowed, stresses will still be above 90% of yield, a KTA 3905 criterion as stated on page 29.

This information is required by the staff to determine compliance with paragraph 607 of IAEA TS-R-1.

2.5 Provide the following references used for the design of the impact limiter:

1) B. Droste, I. Jeschenz Instrumentierte Fallversuche mit dem Transport- und Lagerbehälter für verglaste radioaktive Stoffe CASTOR® VHLW Versuchsbericht Nr. 24063, 18. April 1991. *Instrumented drop tests with the transport and storage cask for vitrified radioactive materials CASTOR® VHLW.*

2) Test findings No. 451183/01. Pressure tests for Assessing the Characteristic Force and Energy Values for the Deformation Behavior of Diverse Types of Wood, RW-TÜV, Essen.

3) GNB B 01/94, Rev. 0. Solidity Behavior of Sample Spruce and Beech Bodies Contained in a Metal Sheet Mantle, under Impact-Upsetting Conditions.

4) R. Diersch, M. Weiß, G. Dreier. Investigations of the Impact Behavior of Wooden Shock absorbers Nuclear Engineering and Design 150 (1994) 341-348.

5) Test Report III.3/10 311, 4th Edition. POLLUX" Test Report - Drop Tests with a Transport and Storage Cask for RAM, BAM, Specialist Group III.3.

6) GNB B 181/2006, Rev. 0. Evaluation of Test Results of Upsetting Tests with Spruce and Beech Wood Samples.

7) M. Weiss. Solidity behavior of spruce wood under impact and upsetting conditions Part 4. German Fuel Institute Freiberg. Activity Area Nuclear Technology. June 1990.

8) F. Drechsler, H. Henker. Solidity behavior of spruce wood under impact and upsetting conditions when fibers are inclined by 20°, 45°, and 70° as related to the position of the stress. Nukem Dresden GmbH Freiberg, 1992.

9) GNB B 125/2005, Rev. 0. "Assessing Static and Dynamic Wood characteristics at RT and minus 40 °C".

These references are required to determine the impact limiter's ability to perform adequately with respect to the 9 m drop test.

This information is required by the staff to determine compliance with paragraph 704 of IAEA TS-R-1.

2.6 Provide the following references used for the design of the cask body and lids:

1) GNB WS 0.7040-12, GNB WS 0.7040-04, GNB WS 0.7040-07.

2) GNB B 115/2004, Rev. 0. Similar Images of the Material Characteristics of Test Samples.

These references are required to determine if the ductile cast iron body and lids perform adequately with respect to the 9 m drop test.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.7 Provide the following references used for the design of the cask body and lids:

1) FKM-Richtlinie, 1. Ausgabe 2001. Bruchmechanischer Festigkeitsnachweis, *Fracture mechanical strength analysis.*

2) AD Instruction W3/2 Issue 6.85 Table 4b. Mentioned referenced in Table 2 GNB B 337/2003 on page 49.

3) BAM Official Publication Gazette, Volume 15, No. 1, March 1985. Ductile Cast Iron with Spheroidal Graphite as a Material for Transport and Storage Casks for Irradiated Fuel Assemblies. K.-E. Wieser, B. Droste, R. Helms, J. Ziebs, J. Hemptenmacher.

4) German Fuel Institute Freiberg GmbH, Freiberg 1990. Solidity Behavior of GGG 40 under Impact-Upsetting Conditions at Low Temperatures.

5) German Fuel Institute Freiberg GmbH, Freiberg 1990. Solidity Behavior of GGG during Impact-Upsetting under 9 m Drop Test Conditions.

6) GNB B 029/2003, Rev. 0, March 2003. Material Data Report for Transport and Storage Cask CASTOR® HAW28M

7) MPA, Stuttgart, Research Project 1500825, 05/1994. Crack Behavior under dynamic Stress Final Report, MPA Order No. 8710 02 000. Part 1: Introducing Chapters and Material Characterization.

8) Technical Note EF04005, Rev. 1. Material Flow Curve for Ductile Cast Iron under Tensile Stress.

9) Technical Note EF04006, Rev. 0. Evaluating the Stress Level on Local Points subject to Overelastic Stress in the Cask Body, Related to the Conservation of Integrity.

10) GNB Report B 291/2003, Rev. 0. Examination and Evaluation of the Quasi Statistic Fracture Mechanical Behavior of Transport and Storage Casks made of Ductile Cast Iron, with the Assistance of the FKM Guideline.

11) Technical Note E2004/0012, Rev. 0. ANSYS Validation for Fracture Mechanical Verifications.

12) FKM Guideline, 1st Edition 2001. Fracture Mechanical Solidity Verification.

The references are required to determine the ductile cast iron body fracture resistance during the 9 m drop test.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.8 Describe the forces that are observed in the bolts within the primary lid, secondary lid, ring, and protection plate during the side drop tests.

Pages 34-44 of document GNB B 251/2005 E illustrate stresses and strains observed during the side drop / slap down conditions. However, neither the models nor the figures depicted describe the forces observed by the bolts in this area.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.9 Clarify the modeled interaction between the protection plate and the ring.

Pages 29 of document GNB B 337/200 states that contact elements of the finite element model are used "wherever there is the possibility of force transfer between the individual elements." However, Figure 19 does not show a contact element between the pressure plate and the ring.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.10 Clarify the yield strength of the ductile cast iron (GGG-40) used as a function of thickness.

Page 18 of document GNB B 082/2000 E states that material properties for ductile cast iron have been estimated for up to a 300 mm thickness. Clarify how these values were obtained for component thicknesses up to 370 mm.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.11 Provide the following reference used for the design of the pressure switch:

GNB B 53/94, Rev. 0. Numerische Analyse des Druckschalters DPS 220 bei IAEA-9-m-Fallsituationen Numerical analysis of the pressure switch DPS 220 in IAEA 9-m drop situations.

The reference is required to determine the performance of the pressure switch during the 9 m drop test.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.12 Describe how the impact limiter(s) will remain in place if one of the tow rods is struck directly from the bar specified under drop II of Section 727.

If one of the tow rods connecting both impact limiters is struck by the rod described in drop II, it is unclear if the impact limiter will remain in place on the package due to the torsional force generated from the strike on to the remaining tow bar and hardware attached to the trunnions. The package's ability to survive the 9 m drop specified in drop I, due to cumulative damage effects specified in Section 726, without an impact limiter, then becomes unclear.

This information is required by the staff to determine compliance with paragraph 727 of IAEA TS-R-1.

2.13 Describe the forces observed in the bolts within the primary lid, secondary lid, ring, and protection plate, during the 1 m bar drop penetration test.

Page 127 of 142 of the document GNB B 337/2003, figures 60 and 61, illustrates the strains observed form the 1 m bar penetration test. However, neither the models nor the figures describe the forces observed by the bolts in this area.

This information is required by the staff to determine compliance with paragraph 727 of IAEA TS-R-1.

2.14 Provide the following information needed to verify the materials properties of the cask components.

1) Material data specifications WB 46 and WB46a for the socket head screws of the primary containment lid, including grade for strength class 8.8.

2) Material standard specification for the shock absorber bottom-side DIN EN 10137-2 (Steel 1.8983).

3) Reference for Young's modulus of GGG cask body material (Wb 38a) at 20ºC in Table 2 of Report No. GNB B 337/2003: *Palmer, K. B.: The mechanical and physical properties of engineering grades of cast iron up to 500°C, Report 1717, November 1987.*

4) Reference for materials properties of GGG cask body material at 75ºC in Table 3 of Report No. GNB B 337/2003: *AD Instruction W 3/2 Issue 6.85 Table 4b. Conversion of tensile yield point and tensile strength based on the values for GGG40 according to AD Instructions W 3/2.*

5) Reference for yield and tensile stresses for 20°C to 50°C in Table 3 of Report GNB B 081/2000 E: *AD Instruction Sheets W 3/1, W 7 and W 13.*

6) Reference for Young's modulus of material for the socket head screws of the primary containment lid (WB 46 and WB46a), given in Table 3 of Report GNB B 081/2000 E: *SEW 310, Physical Characteristics of Steels, Steel-Iron Material-Leafs (SEW) of the Union of German Iron Works Members, 08.1992.*

7) Material standard specifications for primary lid materials St 52-3 (Steel 1.0570, specification WB 44a, b, c) and Fe 510 D1 (Steel 1.0570), including tensile strength and fracture strength data at low temperature (-40ºC). The yield and tensile stresses in Table 3 of Report No. GNB B 337/2003 and Table 3 of Report No. GNB B 082/2000 E is given for the design temperature of 75°C.

8) Materials standard specification for primary lid material TSt E 355 (Steel 1.0562). Include data to justify the statement in Report No. GNB B 082/2000 E that this material has sufficient ductility at low temperatures (e.g., -40ºC).

9) English translations of Table 3, "Material characteristic values for the cask body and lids," and Table 4, "Material characteristic values for the lid bolts," in Report GNB B 082/2000 E. Provide the references cited in that table for the elastic modulus for the materials GGG, St 52-3, Fe 510 D1, and TSt E355.

10) Reference discussing relationship of materials properties with cask body wall thickness, cited in Report No. BAM GGR 007: Rehmer, B., Kühn, H., Weidlich, S., and Frenz, H.: BAM Production Control Programme for Containers for Transport and Storage of Nuclear Materials, RAMTRANS 6 (1995) Nos. 2-3, pp. 205-209.

11) English translation of data reviewed in Reference 104 of Report No. BAM – GGR 007, which provided the basis for the bounding dynamic fracture toughness (K_{ID}) value of 30 MPa $m^{1/2}$ for the lowest design temperature of -40ºC (once accounting for 3σ for the measured minimum K_{ID} of 50 MPa $m^{1/2}$). The data in Reference 104 appears to also consider data from other multiple sources (References 53, 100, 101, 102, and 103 in Report No. BAM – GGR 007), which provided a basis for the conclusions in Reference 104. A concise summary with translated plots from these references, and method and conclusions in Reference 104 would be sufficient. *Bundesanstalt für Materialforschung und -prüfung: Ermittlung von bruchmechanischen Werkstoffkennwerten von Gußeisen mit Kugelgraphit bei dynamischer Beanspruchung, Unveröffentlichter Zwischenbericht zum BAM-Projekt 0207-V-0220 .Erarbeitung eines Begutachtungskonzeptes für den Einsatz von Gußeisen mit Kugelgraphit für Transport- und Lagerbehälter unter Berücksichtigung erhöhter Beanspruchungsgeschwindigkeiten., BAM-V.31, Berlin, 28. Februar 2000.*

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

2.15 Provide data supporting the assumption that the critical stress intensity factor (K_{IC}) at -40°C is also valid for dynamic stress conditions (K_{ID}) for the GGG cask body material. The data should address test sample microstructure (pearlite/ferrite content, nodular graphite size and distribution) and be obtained by test methods consistent with applicable consensus codes and standards. Discuss any fabrication controls in the CASTOR® THTR/AVR package to ensure the assumption remains valid.

The discussion of the 9 m side drop test in Report No. GNB B 251/2005 E includes a conclusion that the calculated stress intensity factor does not exceed a constant stress intensity factor (K_{IC}) of 50 MPa.m$^{1/2}$. Report No. BAM – GGR 007 states that under dynamic stress conditions (strain rate $\varepsilon \geq 0.1\ s^{-1}$), a significant reduction in fracture toughness is observed between the temperature range of -20ºC and -40ºC. The report states that dynamic fracture toughness (K_{ID}) values down to 30 MPa.m$^{1/2}$ have been obtained (References 53, 100, 101, 102, 103 in Report No. BAM – GGR 007 – not provided in the application). The report further cites another BAM study (Reference 104 – not provided in the application) with a minimum fracture toughness value of 50 m$^{1/2}$ for large test specimens (maximum pearlite contents up to 20%).

However, Report No. BAM – GGR 007 recommended a design maximum K_{ID} value of 30 MPa m$^{1/2}$ for the lowest design temperature of -40ºC, due to the limited number of samples studied in Reference 104. The staff has not received the cited references in Report No. BAM – GGR 007 and is unclear if additional studies have been performed to justify that the assumed maximum K_{IC} value of 50 MPa m$^{1/2}$ is bounding for dynamic stress conditions. The data provided should be clear on the test sample microstructure (ferrite and pearlite composition, nodular graphite size and distribution), and be obtained by test methods consistent with applicable consensus codes and standards. The applicant is also asked to discuss any fabrication controls to ensure that the assumed critical stress intensity factor remains valid for the fabricated package. Note that standard specification GNB WS 0.7040 was not included in the application and has been requested in RAI 2.6.

This information is required by the staff to determine compliance with paragraph 705 of IAEA TS-R-1.

III Thermal Evaluation

3.1 Provide the minimum and maximum allowable temperature limits and the associated reference for those allowable temperature limits for the AVR-TL contents and cast iron cask body during normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

The application did not include the allowable temperature limits (minimum and maximum) for the AVR-TL contents and cast iron cask body during NCT and HAC. The staff is unable to confirm that the thermal analysis temperatures are above and below the respective minimum and maximum allowable temperature limits.

This information is required by the staff to determine compliance with paragraphs 651(a), 676, and 807(f) of IAEA TS-R-1.

3.2 Provide an evaluation of thermal stresses caused by constrained interfaces among package components (e.g., lids, bolts, shielding material, etc.) resulting from temperature gradients and differential thermal expansion during NCT, and during and after HAC.

The application did not include an evaluation of thermal stresses during NCT, nor during and after HAC. The evaluation should include necessary material properties, such as thermal expansion coefficients of the package components. The evaluation should be

for the AVR-TL contents, or show how the evaluation is bounding for the AVR-TL contents.

This information is required by the staff to determine compliance with paragraphs 651(b), 656, and 728 of IAEA TS-R-1.

IV Containment Evaluation

4.1 Demonstrate that the entire containment boundary can satisfy the criteria specified for a leak-tight designation per ANSI N14.5.

Staff does not have reasonable assurance that the entire containment boundary has been thoroughly evaluated. While the lid and seal region of the containment boundary has been fully characterized and tested to the leak-tight standard of ANSI N14.5, the applicant has not demonstrated the same level of rigor for the ductile iron cask (package) body. Without fabrication leakage testing, or subsequent leakage testing of any kind for the cask body, staff is unable to confirm that the containment boundary satisfies the relevant regulations of IAEA TS-R-1. Furthermore, it is unclear to staff whether damage due to the tests for normal conditions of transport or hypothetical accident conditions could exacerbate potential defects in the ductile cast iron relevant to the containment function.

This information is required by the staff to determine compliance with paragraphs 501(b) and 502(e) of IAEA TS-R-1.