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Compliance of the Type B(U)F Package Transport and Storage Cask CASTOR® THTR/AVR with Containment Requirements

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1 Introduction

The CASTOR® THTR/AVR Type B(U)F package (the cask) is designed to accommodate radioactive material from the thorium high temperature reactor THTR-300 and the high temperature reactor of the Arbeitsgemeinschaft Versuchsreaktor GmbH (AVR). The approved AVR inventory consists of up to 1900 fuel elements (FE) from the AVR reactor in each packaging [1]. The CASTOR® THTR/AVR Type B(U)F packages are to be transported from Germany to the United States of America. US regulations require periodic leakage rate testing and pre-shipment leakage rate testing of the whole cask containment including its structural components.

If the leak-tightness of structural components was proven in a fabrication leak-tightness test, it is accepted to restrict subsequent leak-tightness testing to the sealing system of the cask. For the structural components of the CASTOR® THTR/AVR casks, which are already loaded, no fabrication leak-tightness test was performed. Yet, periodic and pre-shipment tests of the structural components are not feasible anymore. To compensate for this, [redacted] to demonstrate that leakage through structural components of a CASTOR® THTR/AVR would not occur.

In this report, the overall compliance of the CASTOR® THTR/AVR, loaded with AVR inventory, with the containment requirements is demonstrated.

2 Admissible leakage rate

Admissible activity release rates and reference air leakage rates of the containment system are determined in the containment analysis report (GNS B 325/2018, Rev. 2 [2]) based on the containment criteria in 10 CFR 71 [3] and taking into account the relevant boundary conditions of the CASTOR® THTR/AVR and the AVR inventory. A reference air leakage rate of L = [redacted] (corresponding to a standard helium leakage rate of L = [redacted]) is obtained for the most restricting case NCT.

3 Containment boundary

The containment boundary for the CASTOR® THTR/AVR with AVR inventories is constituted alternatively by the following subassemblies (see [4]):

a) Containment with primary lid (1st sealing barrier)
   - cask body (item 2),
   - primary lid (item 19) and socket head screw (item 32), socket head screw for plumbing seal (item 34) and metal O-ring (item 42 (Al)), as well as
   - protection cap (item 61) in the primary lid, socket head screw (item 39) and metal O-ring (item 73 (Al)).

b) Containment with secondary lid (2nd sealing barrier)
   - cask body (item 2),
   - secondary lid (item 55) and socket head screw (item 62), socket head screw for plumbing seal (item 64) and metal O-ring (item 70 (Al)),
   - protection cap (item 61) in the secondary lid, socket head screw (item 39) and metal O-ring (item 73 (Al)), as well as
   - blind flange (item 89), socket head screw (item 39) and metal O-ring (item 71 (Al)).

The potential leakage paths for the containment with primary lid are depicted in Figure 1. The potential leakage paths for the containment with secondary lid are depicted in Figure 2.

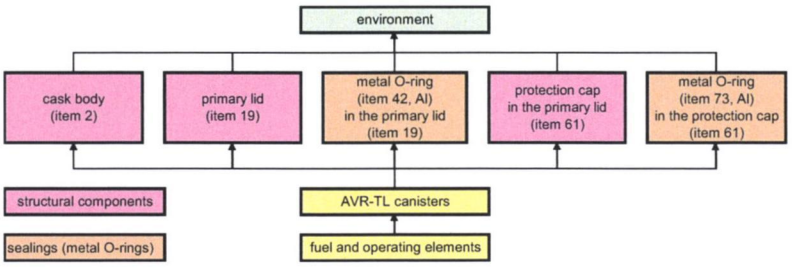

Figure 1: Leakage paths for containment with primary lid

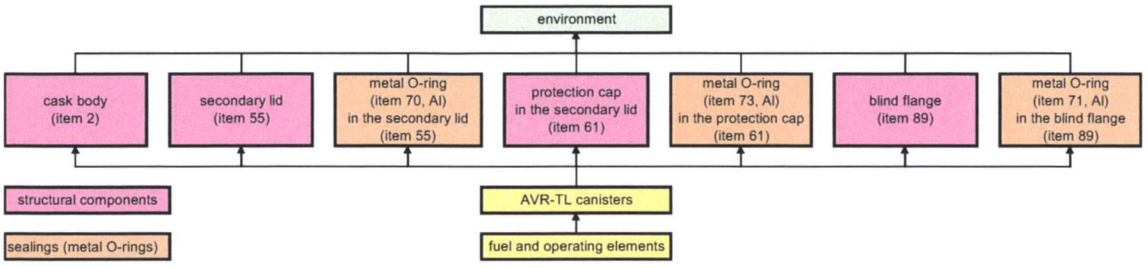

Figure 2: Leakage paths for containment with secondary lid

Compliance with the admissible reference air leakage rate (resp. standard helium leakage rate) and, hence, compliance with the containment criteria, has to be demonstrated based on leak-tightness tests. The tests are performed according to helium leak-tightness test procedures defined in test specifications. The acceptance criteria established in the test specifications are chosen in such a way that compliance with the reference air leakage rate follows from compliance with the acceptance criteria.

4 Leak-tightness of the lid sealings (metal O-rings) of the primary or secondary sealing barrier

Compliance with the reference leakage rate of the lid sealings of either the containment with primary lid (i. e. the metal O-ring 42 and item 73) or the containment with secondary lid (i. e. the metal O-rings (item 70, item 71, item 73) has to be proven for each loaded CASTOR® THTR/AVR prior to the transport. The applicable helium leak-tightness test procedure is defined in PV 360/17, Rev. 2 [5] according to WKP no. 500.07-03 [6]. The admissible total standard helium leakage rate (acceptance criterion) for the lid sealings of the primary or secondary lid sealing are:

[redacted]

equivalent to a reference air leakage rate of [redacted].

It should be noted that the testing prior to transport according to [5] effectively includes either a testing of the structural component protection cap (item 61) in the primary lid (for the containment with primary lid) or a testing of the structural components protection cap (item 61) in the secondary lid and blind flange (item 89) (for the containment with secondary lid), even if the measured leakage rate is attributed to the metal gasket, as the test arrangement includes the test adapter of type AF, with which the whole external side of the protection cap or blind flange is covered to constitute the test space (cf. [7]).

5 Leak-tightness of the structural components of the primary or secondary sealing barrier

The leak-tightness of the cask's structural components of the secondary sealing barrier including the cask body (item 2), the secondary lid (item 55), the protection cap (item 61) in the secondary lid, and the blind flange (item 89) was determined with a helium leak-tightness test [redacted] With this, the components of the secondary sealing barrier which are not subject to testing before transport (cf. Figure 2 and Section 4) are addressed.

[redacted] The occupational radiation exposure that would result from routine tests on the structural components of the loaded casks cannot be justified, as no leakage through the structural components needs to be expected.

The corresponding tests were performed according to the test procedure PV 360/82, Rev. 3 [8], which was accepted by an ASNT level III certified expert, in the period from 2020-09-21 to 2020-11-11 [redacted]. In [8], the target value for the admissible total standard helium leakage rate of the cask's structural components of the secondary sealing barrier including the cask body was predefined to:

[redacted],

equivalent to a reference air leakage rate of [redacted]

The test report is given in [9]. The measurements yielded an integral standard helium leakage rate of the above mentioned components of [redacted], equivalent to a reference air leakage rate of [redacted], fulfilling the target.

This leakage rate is also covering the one that can be expected for the structural components of the primary sealing barrier which are not subject to testing before transport (cf. Figure 1 and Section 4), namely the cask body (item 2), the primary lid (item 19) and the protection cap (item 61) in the secondary lid.

[redacted]

It should be noted that

- [redacted]
- potential leakage through protection cap and, for the containment with secondary lid, also blind flange is effectively included in the leakage rate which is measured prior to transports and attributed to the metal gasket of the respective component (see Section 4).

6 Conclusion

The total leakage rate of the CASTOR® THTR/AVR cask is the sum of the leakage rates of the lid sealings (max. [redacted] confirmed prior to transport with leak-tightness testing, see Section 4) and of the structural components of the cask [redacted]), yielding a total reference air leakage rate of max. [redacted]

This value is [redacted] below the admissible reference air leakage rate of [redacted], as deduced in [2], and even lower than the requirement that would result from neglecting all retention mechanisms for H-3, C-14 and Kr-85, i. e. [redacted]. Due to this large safety margin between total expectable leakage rate of the transported casks and the admissible leakage rates, also credible potential variations [redacted] cannot lead to inadmissible activity release from a CASTOR® THTR/AVR cask with AVR inventory as long as the acceptance criteria of [5] are fulfilled prior to transport. Therefore, no modification of [5] is required and the overall compliance of the CASTOR® THTR/AVR cask, loaded with AVR inventory, with the containment requirements is demonstrated.

List of Figures

List of References

[1] Certificate of Approval
D/4214/B(U)F-96, Rev. 11

[2] GNS B 325/2018, Rev. 2
Containment Analysis for the Type B(U)F Package
Transport and Storage Cask CASTOR® THTR/AVR

[3] U.S. Nuclear Regulatory Commission Regulations: Title 10,
Code of Federal Regulations, Part 71

[4] GNB B 348/2003, Rev. 0
Typ B(U)F-Versandstück
Transport- und Lagerbehälter CASTOR® THTR/AVR
Behälterbeschreibung
Type B(U)F Package Transport and Storage Cask CASTOR® THTR/AVR Description of the Packaging

[5] PV 360/17, Rev. 2
Dichtheitsprüfung
Helium-Dichtheitsprüfverfahren
- CASTOR® THTR/AVR -
- Beladung -
Test specification Leak-tightness test Helium leak-tightness test procedure
- CASTOR® THTR/AVR - Loading -

[6] WKP 500.07-03, Index 12
Plan for periodic inspections of a loaded CASTOR® THTR/AVR transport and storage cask prior to transport on public transport routes

[7] PV 360, Rev. 6
Basisprüfvorschrift
Dichtheitsprüfung
Helium-Dichtheitsprüfverfahren
Basic test specification - Leak-tightness test - Helium leak-tightness test procedure

[8] PV 360/82, Rev. 3
Test specification
Cask structural component – Leak-tightness test
Helium leak- tightness test procedure
- CASTOR® THTR/AVR -

[9] GNS T 280/2020, Rev. 0
Results of the leak-tightness testing of the CASTOR® THTR/AVR cask with [redacted]