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HELIUM LEAK TESTING REQUIREMENTS AND EXPERIENCES ON TRANSPORT AND STORAGE CASKS FOR INTERIM STORAGE IN SWITZERLAND

S. Flechsig
SVTI-N
Swiss Association for
Technical Inspections
Nuclear Inspectorate

N. Catoja
SVTI-N
Swiss Association for
Technical Inspections
Nuclear Inspectorate

F. Peter
SVTI-N
Swiss Association for
Technical Inspections
Nuclear Inspectorate

U. Röder-Roith
SVTI-N
Swiss Association for
Technical Inspections
Nuclear Inspectorate

ABSTRACT

This paper provides an overview of the actual surveillance requirements of the Swiss Federal Nuclear Safety Inspectorate, ENSI, relating to helium leak testing on dual-purpose casks for interim storage of nuclear waste in Switzerland.

The requirements are summarized in the “Regulatory Guideline for Swiss Nuclear Installations” (ENSI-G05). The defined limit of standard helium leakage rate (SHeLR) for each barrier function seal of the containment system is 10^{-8} Pa m^3/s. In addition, the ratio of the sum of all these SHeLRs to the volume of the monitored space must not exceed 2* 10^{-6} (Pa m^3/s)/m^3.

These values have to be verified for all casks by measurements during the final inspection at the manufacturers’ site as well as after loading and immediately before the interim storage. The supervision of these measurements and the review of the underlying test procedures according to national and international standards for leak testing on storage casks of radioactive materials have been delegated by ENSI to SVTI-N.

In the last twenty years, the test procedures have been improved based on the experiences from measurements. For example, the leak testing requirements have been adapted to include the storage conditions. The typical storage casks used in Switzerland must have a double-lid system with metallic seals. Each lid forms a barrier and shall have the ability to provide the leak tightness of the cask.

The inner lid closes the storage volume and has a metallic seal on the inner side and an elastomer O-ring outside. The volume between both seals is used for the measurements. The outer lid has the same sealing principle, which closes the cask from the environment.

In the storage configuration, the volume between the lids is pressurized with helium (6.5 bar). This pressure is permanently monitored and an abnormal pressure loss indicates a failure.

The nominal pressure in the main storage volume is below atmospheric pressure (0.2 bar helium). In our presentation we will cover the individual steps of the leak testing procedure and mention in particular the test with elevated pressure (7.0 bar), which turned out to reveal a significant difference between reliable and potentially error-prone sealing.

INTRODUCTION

In accordance with the Regulatory Guideline for Swiss Nuclear Installations [1], the leak tightness of the transport and storage casks for interim storage in Switzerland must be verified on each cask after the manufacturing, after loading and prior its storage. On behalf of the Swiss authority ENSI, SVTI-N, as a Type A inspection body according to ISO/IEC 17020 [2], is in charge of supervising the leak tightness testing of these casks.

The supervision has to assure that the following requirements defined in [1] are fulfilled:

- The standard helium leakage rate (SHeLR) for each barrier function seal of the containment system shall be less than 10^{-8} Pa m^3/s.
- The ratio of the sum of all of these SHeLRs to the volume of the monitored space must not exceed $2*10^{-6}$ (Pa $m^3/s)/m^3$, whereas the monitored space is the volume between the lids in storage condition.

The defined limit of standard helium leakage rate (SHeLR) of 10^{-8} Pa m^3/s can only be evaluated by the tracer gas method. For this reason, helium is used as tracer gas on the leak tightness tests of transport and storage casks for interim storage in Switzerland.

The SVTI-N activities to supervise the tightness tests consist of:

1. The review of the applicable test specifications by an authorized inspector with level 3 certificate in leak testing according to [3] before the start of the leak tests.
2. Supervision of leak tightness testing after manufacturing, after loading with nuclear waste and before interim storage.
3. Reporting to ENSI about the results of the SVTI-N supervision.

The basis of the supervision activities are the underlying Safety Analysis Report for the storage configuration, which has been approved by ENSI for each cask type. The supervision of these measurements and the review of the underlying test specification have to be carried out according to national and international standards for leak testing on storage casks of radioactive materials.

1. REVIEW PROCESS OF THE APPLICABLE TEST SPECIFICATIONS

The helium leak testing after manufacturing is part of the final acceptance inspections of each cask. For that, the applicable test specification shall be issued by the organisation, which will perform the leak tests. Afterwards these specifications shall be reviewed and accepted by the designer and the future owner of the cask.

The test specification for leak testing after loading is issued by the operator of the nuclear power plants, while the test specification for leak testing before storage is issued by the responsible operators of the interim storage facilities in Switzerland, ZWILAG and ZWIBEZ.

If the test specifications comply with the underlying Safety Analysis Report, the Regulatory Guideline for Swiss Nuclear Installations [1] and the applicable national and international standards [3], [4], [5], [6] and [7], they are accepted with the SVTI-N stamp “Requirements fulfilled”.

2. SEALING SYSTEM

According to the current regulatory guideline [1], storage casks for spent nuclear fuel shall have a double-lid system with metallic seals. Each lid forms a barrier and shall be able to provide the leak tightness of the cask over the entire interim storage period.

Figure 1 shows the cross section of a storage cask with the double seals A and B including the helium pressure during the measurements, left after manufacturing and right after loading and before interim storage. Each lid has at least one orifice, which is closed by an orifice cover. The tightness of these orifice covers is assured by the metallic seals C and D.

The inner lid assures the casks main containment function and has a metallic seal on the inner side and outside usually an elastomer O-ring (Figure 1; reference A). The volume between both seals creates a testing room, which is used for the leak tightness measurements. The outer lid has the same sealing system and assures the containment of the cask from the environment (Figure 1; reference B).

3. LEAK TESTING AFTER MANUFACTURING, AFTER LOADING AND BEFORE INTERIM STORAGE

The following helium leak tightness tests are performed at the manufactory:

- the first sealing barrier (Figure 1; sealing A and C) with a helium pressure of 1.0 bar;
- the second sealing barrier (Figure 1; sealing B and D) with a helium pressure of 7.0 bar.

The use of 1.0 bar testing pressure at the first sealing barrier is similar to standard conditions and a conservative assumption compared to the storage configuration. The applied pressure at the second barrier reproduces nearly the conditions of the loaded casks in the interim storage plants in Switzerland. The measurement at 7.0 bar includes some safety margin.

After loading in the nuclear power plant, the leak tightness test of the first sealing barrier (Figure 1; sealing A and C) is performed with a helium pressure of 0.2 bar in the cavity. The second barrier is often only used in transport configuration and therefore not in the scope of this paper.

Actually, at the interim storage facilities ZWILAG or ZWIBEZ, the first sealing barrier (Figure 1; sealing A and C) is currently tested again, to confirm that the standard helium leakage rate still fulfils the criterion of $\leq 10^{-8}$ Pa m^3/s after the transportation and handling. Afterwards, the tightness test of the second sealing barrier is performed under storage configuration with a pressure of 6.5 bar helium.

4. DEVELOPMENTS BASED ON THE EXPERIENCES FROM MEASUREMENTS

The regulatory guideline [1] defines the requirement for the containment function. For each barrier function seal of the containment system, the SHeLR limit is 10^{-8} Pa m^3/s (technical tightness) and the minimum ratio of the sum of all these SHeLRs to the volume of the monitored space 2* 10^{-6} (Pa m^3/s)/m^3.

The first tightness tests of a transport and storage cask with SVTI-N surveillance took place in the year 2001, when the first cask for high active nuclear waste was stored in the interim storage facility in Switzerland (ZWILAG). At this time, the leak testing at both barriers was carried out with a pressure of 1.0 bar (similar to standard conditions).

During the last twenty years, the test specifications have been further developed based on experiences from measurements.

The use of 1.0 bar testing pressure at the first sealing barrier is similar to standard conditions and conservative compared to the storage configuration. However, the outer lid was tested only under standard conditions with 1.0 bar, even if the casks were stored with 6.5 bar helium pressure in the monitored space.

To take into consideration the conditions in the storage facilities in Switzerland, it was agreed that the helium tightness test on the secondary barrier shall be performed with 6.5 bar prior storage and with at least 6.5 bar after the manufacturing.

The implementation of this improvement led to a further discussion concerning the conversion approach for the standard helium leakage rate calculation, depending on the expected flow form at a pressure of 6.5 or 7.0 bar.

Depending on the transverse section of the leak and for a pressure gradient in the range of 6.5 - 7.0 bar, the kind of flow can be molecular or viscous laminar. In the technical literature, there are various approaches for the differentiation between viscous laminar and molecular flow.

According to [5] and [6], the molecular flow can be found approximately in the leakage range of < 10^{-7} Pa m^3/s, while the viscous laminar flow is given higher than 10^{-5} Pa m^3/s for a single capillary leak. In comparison, in [7] the molecular flow is quantified in the range of < 10^{-6} Pa·m^3/s standard leakage rate (SLR) and the viscous laminar flow between < 10^{-2} Pa·m^3/s SLR and 10^{-7} Pa·m^3/s SLR.

Due to these approaches, the flow form in the leak cannot be exactly determined and the conservative value of the leakage shall be considered. For the expected range of leakage rate < 10^{-8} Pa m^3/s, the molecular flow must be assumed according to [7]. Therefore, the molecular flow is considered using the formula (1) for the calculation of the SHeLR in the applicable helium tightness test specifications.

$$Q_L = SHeLR \cdot \frac{p_2 - p_1}{p_{amb}}$$ molecular flow (1)

$$Q_L = SHeLR \cdot \frac{p_2^2 - p_1^2}{p_{amb}^2}$$ viscous laminar flow (2)

with:

p_1 the lower pressure

p_2 the higher pressure

p_{amb} ambient pressure

If the formula for molecular flow (1) is used, the resulting limit of helium leakage rate at 7.0 bar is 7* 10^{-8} Pa m^3/s. In comparison, the calculation with (2) for viscous laminar flow gives 4.9* 10^{-7} Pa m^3/s. This calculation shows that the consideration of the molecular flow is conservative compared to the viscous laminar approach.

It is common practice to do the calculation with both approaches and to consider the conservative case [8]. Therefore, the leakage rate in test condition at 6.5 and 7.0 bar shall be calculated with the molecular flow formula for the tightness test of the outer lid and their orifice cover for transport and storage casks in Switzerland.

Furthermore, the practical experience shows that the sealing system of the outer lid is gradually reaching its limits with a helium pressure of 7.0 bar. The filling of the volume between the lids should be done slowly with holding time to allow the sealing to adapt. The metallic seal of the outer lid failed several times, while testing the outer lid with elevated pressure at 7.0 bar. The test with 1.0 bar or 0.2 bar failed rarely. If the tests fails, the leak test must be repeated after appropriate measures and with a new seal.

In summary, the leak test at 6.5 or 7.0 bar and the correct interpretation of the measured leakage rate are important methods to ensure the technical tightness of the casks over the entire interim storage period.

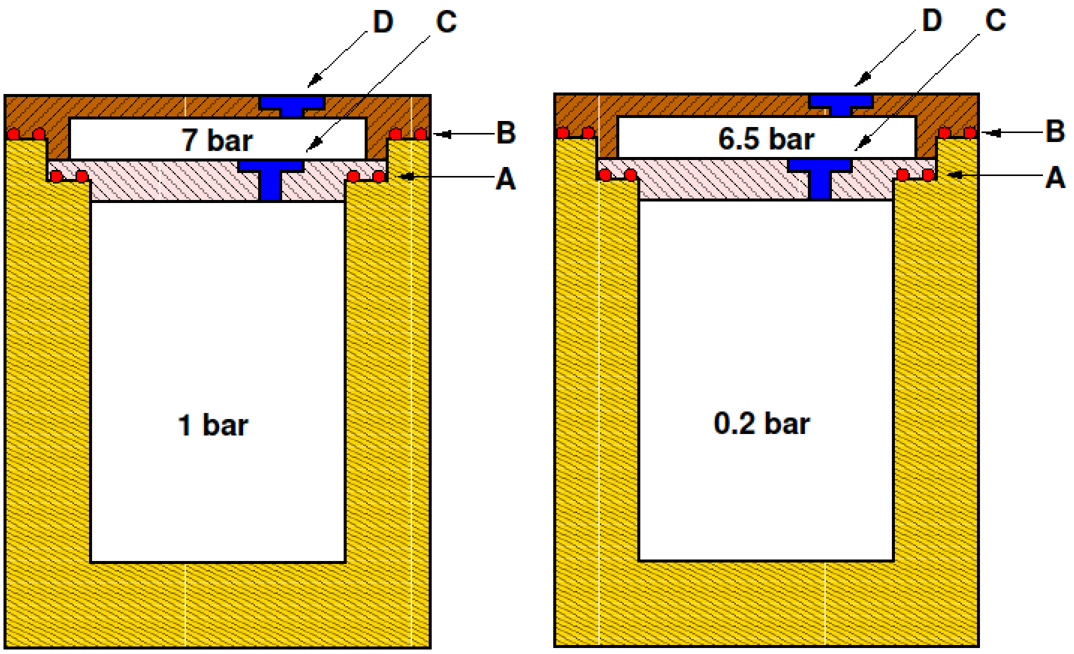

Figure 1. Principle sketch of sealing system. Left: after manufacturing, right: after loading and before interim storage.

CONCLUSIONS

Cask manufacturing for Switzerland is done in various countries by different suppliers. For the manufacturing surveillance, a product-based system is implemented, to ensure that each manufactured cask fulfils the specified parameter coming from the safety files. This paper introduces the leak testing conditions including the requirements coming from the Swiss regulations and the conditions in the storage facilities. Potential manufacturers can implement measures to comply with these conditions up from the beginning to ensure that each cask works correctly.

ACKNOWLEDGMENTS

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REFERENCES

[1] ENSI – Richtlinie ENSI-G05: Transport- und Lagerbehälter für die Zwischenlagerung April 2008 (Änderung vom 20. Dezember 2018).
[2] EN ISO/IEC 17020:2012 Conformity assessment - Requirements for the operation of various types of bodies performing inspection.
[3] ISO 9712:2012 Non-destructive testing - Qualification and certification of NDT personnel.
[4] ISO 20485-2017 Non-destructive testing - Leak testing - Tracer gas method.
[5] SN EN 1779:1999-10 Non-destructive testing - Leak testing - Criteria for the method and technique selection.

[6] SN EN 1779:1999-10/A1:2004 Non-destructive testing - Leak testing - Criteria for the method and technique selection, Amendment A1.
[7] ISO 12807:2018 Safe transport of radioactive materials - Leakage testing on packages.
[8] DGZfP-Fachausschuss Dichtheitsprüfung Richtlinie DP 2, Richtlinie zur Umrechnung der mit Prüfgasen gemessenen Leckageraten in anderen Medien (Gase, Flüssigkeiten), Dezember 2009.