Review of Safety Verification Based on Spent Fuel Dry Storage Cask Opening Experiences

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1. Introduction

Spent fuel generated from commercial nuclear power plants must inevitably be stored for extended periods due to delays in securing a final repository. Accordingly, following the use of wet storage, dry storage systems have been widely adopted, and ensuring the safety of dry storage remains a critical issue from both regulatory and public acceptance perspectives. This study, based on the report *Spent Fuel Dry Storage Cask Opening: Operational Experiences (EPRI, 2025)*, reviews cask opening inspection cases conducted in the United States and Japan, and examines the implications of these findings for safety verification and the establishment of aging management frameworks.

2. Methods and Case Analyses

This study is based on the EPRI Report *Spent Fuel Dry Storage Cask Opening – Operational Experiences (2025)*, which documents four major cask opening inspections. These cases, differing in reactor type, storage duration, fuel, and cask design, provide valuable empirical evidence for verifying the long-term safety of spent fuel and dry storage systems.

2.1 Idaho National Laboratory (CASTOR V/21, PWR)

Background: Fifteen-by-fifteen PWR fuel assemblies from the Surry Nuclear Station, with burnups of 24–35 GWd/MTU and cooling times of 2.2–3.1 years, were loaded into a CASTOR V/21 metal cask and stored for approximately 14 years.

- Inspection Methods: Examinations included visual inspection of the cask exterior, lid seals (metal and elastomer), internal basket structure, fuel assemblies, and selected rods. Assembly T11 was subjected to destructive and non-destructive testing, gas sampling, and oxide layer adhesion evaluation.

- Findings: Lid seals and structural components showed no signs of degradation, except for pre-existing weld cracks caused by thermal expansion during earlier testing. Fuel cladding exhibited tightly adherent oxide layers, with no evidence of cracking, spallation, or fission gas release. Radiation shielding performance remained unchanged compared to baseline measurements in 1985.

- Significance: Even under atypical and severe test conditions, fuel and cask integrity were preserved, demonstrating the robustness of dry storage.

(a) (b) (c)

Fig. 2.1. Inspection results
(a)Lid Bolts, (b)Seals, (c)Cask Wall

2.2 Peach Bottom Atomic Power Station (TN-68, BWR)

- Background: In 2000, 68 BWR fuel assemblies were loaded into a TN-68 dual-purpose cask. After approximately 10 years, a helium pressure drop triggered a conservative decision to return the cask to wet storage for inspection.

- Inspection Methods: Visual examinations of the cask exterior and lid seals, vacuum sipping of all assemblies, and subsequent detailed inspection of bundle LJB992 after an additional 10 years of pool storage.

- Findings: Outer aluminum seals showed localized galvanic corrosion, but the primary metallic seal remained intact. All 68 assemblies were undamaged, with no evidence of fuel rod failure. After 10 years of wet storage, bundle LJB992 exhibited only typical nodular corrosion and crud deposition; structural integrity was preserved.

- Significance: The case demonstrated that fuel integrity is not compromised by transitions between dry storage, rewetting, and subsequent long-term wet storage.

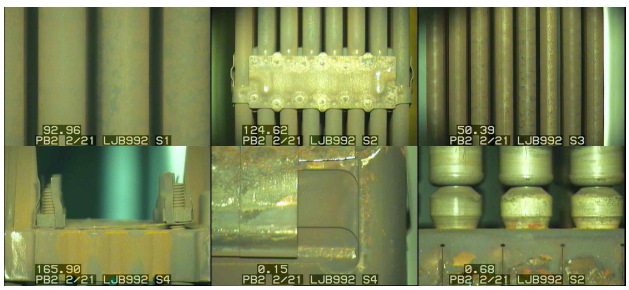

Fig. 2.2. Fuel bundle LJB992 visual observations

2.3 Fukushima Daiichi Nuclear Power Station (KOBELCO, BWR)

- Background: Nine KOBELCO metal casks containing BWR fuel were loaded in 1995. Routine inspections were conducted after 5 and 10 years. Following the 2011 Great East Japan Earthquake and tsunami, the cask storage facility was flooded, prompting comprehensive reinspection in 2013.

- Inspection Methods: Helium leak testing, gas sampling for fission product detection (Kr-85), visual inspection of fuel assemblies, and basket deformation assessments.

- Findings: 2000 and 2005 inspections confirmed fuel and cask integrity. White deposits observed on seals were identified as oxide films from residual pool water, without impact on sealing function. 2013 post-tsunami inspections confirmed all nine casks-maintained safety functions. Some aluminum hydroxide deposits formed from seawater exposure, but no structural damage or fuel failures were observed.

- Significance: This case provides strong evidence that dry storage casks can maintain safety performance even during beyond-design-basis events (BDBEs) such as earthquakes and tsunamis.

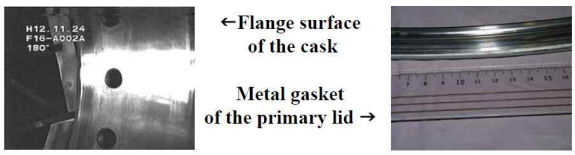

Fig. 2.3. Images of the flange surface of the cask and metal gasket of the primary lid from 2000 inspection

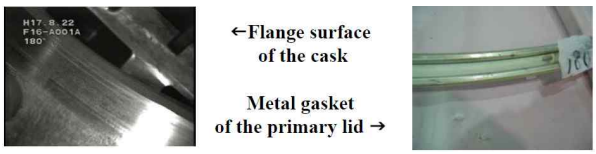

Fig. 2.4. Images of the flange surface of the cask and the primary lid metal seal from 2005 inspection

2.4 Tokai No.2 Power Station (Hitachi Zosen, BWR)

- Background: A Hitachi Zosen cask containing BWR assemblies stored for seven years was opened for inspection.

- Inspection Methods: Leak testing of lid seals, visual inspection of cask body and internal basket, and four-sided fuel assembly examinations.

- Findings: No damage, deformation, or corrosion was observed in either the fuel or cask components. All safety functions (containment, shielding, and heat removal) were preserved.

- Significance: The Tokai case confirmed the long-term integrity of BWR fuel and casks under Japanese dry storage conditions.

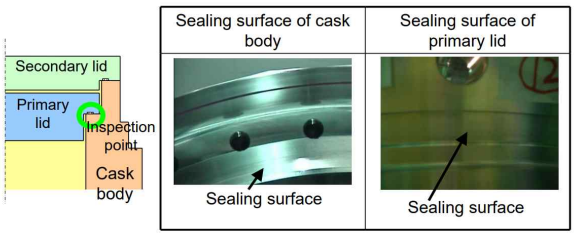

Fig. 2.5. Illustration of inspection point, representative images of cask body and primary lid sealing surfaces

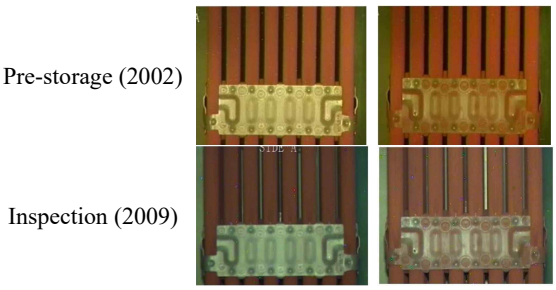

Fig. 2.6. Fuel assemblies selected for inspection from cask

3. Discussion

The reviewed cases demonstrate that during dry storage periods of up to 14 years, no significant degradation or loss of safety functions was observed in either the fuel or the storage casks. In particular:

- Fuel cladding integrity: Gas sampling and visual inspections confirmed that no additional fuel damage occurred as a result of dry storage.

- Cask structural integrity: Although some localized defects, such as corrosion, discoloration, or weld cracks, were identified in structural components, shielding materials, and seals, these did not impair the overall safety functions of the casks.

- Response to beyond-design-basis events: The Fukushima Daiichi case provided empirical evidence that dry storage systems can maintain integrity and safety functions even under extreme external events that exceed design basis assumptions.

4. Conclusion

This study reviewed spent fuel dry storage cask opening cases and compiled empirical data necessary for safety verification. The results confirmed that during storage periods of 10–14 years, both fuel assemblies and casks maintained their integrity, providing an important technical basis for the feasibility of long-term dry storage and the establishment of regulatory frameworks. In particular, the cases and data presented

in this study will serve as valuable references that can directly support the safety verification and institutional development of the dry storage program currently being pursued in Korea. Future work should include examinations of longer storage durations and further verification across diverse cask designs.

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