SAND2011-2612P

Containment Evaluation / Leakage Testing

KRMC Discussion

April 18, 20, and 22, 2011

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Containment Evaluation / Leak Testing Topics

- Welcome
- Status of KRMC containment and leak testing work
- Review topics
  - Containment evaluation of Type B cask for spent fuel
  - Containment evaluation of Type A cask for non-spent fuel
  - Containment evaluation for spent fuel dry storage system
  - Leak testing of spent fuel cask
  - Leak testing of non-spent fuel cask
  - Real time leak testing at drop test

Containment Evaluation for Spent Fuel Casks

Guidance Documents for Containment Evaluation for Spent Fuel Casks

In the U.S., we recommend the following documents to prepare safety analysis reports for spent fuel

- **U.S. Nuclear Regulatory Commission (NRC) 10CFR71 Packaging and Transportation of Radioactive Materials**
- **NUREG-1617 "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel"**
- **ANSI N14.5 "American National Standard for Radioactive Materials – Leakage Tests of Packages for Shipment"**
- **NUREG/CR-6487 "Containment Analysis for Type B Packages Used to Transport Various Contents"**

The discussion will reference these documents as well as our experiences.

Definitions

- Definition of “Containment System” in 10CFR71.4
  - The assembly of components of the packaging intended to retain the radioactive material during transport.
- Definition of “Confinement System”:
  - For radioactive materials packaging, a confinement system provides a means to prevent dispersal of materials (particulates).
  - Not adequate for Type B casks

Definitions

- Type A quantity – quantity of radioactive material, the aggregate radioactivity of which does not exceed A_1 for special form radioactive material, or A_2 for normal form radioactive material. The A_1 and A_2 values are found in Table 1 of 10CFR71. [Ref. 10CFR71.4]
- Type B quantity – quantity of radioactive material greater than a Type A quantity. [Ref. 10CFR71.4]
- Leak tight – leakage rate of $\leq 10^{-7}$ ref. cm^3/s (reference air leakage rate) at an upstream pressure of 1 atm and downstream pressure of 0.01 atm abs or less.

Definitions - continued

- Reference air leakage rate – volumetric flow rate of dry air at 298 K leaking from a pressure of 1.0 atm to a pressure of ≤ 0.01 atm
- Leakage rate – volumetric or "mass-type" leakage rate from a container (cm^3/s or ref. com^3/s).
- Release rate – rate of radioactive release as a function of time (Ci/s)
- CRUD – fully, easily removed CRUD composed mostly of hematite that is usually found on BWR rods, or a tenacious type composed of nickel-substituted spinel occurring on PWR rods.

10CFR71 Packaging and Transportation of Radioactive Material

- Containment Criteria for Type B Packages are defined in 10CFR71
  - Normal conditions of transport – as demonstrated to a sensitivity of 10^{-6} A_2 per hour
  - Hypothetical Accident Conditions – no escape of radioactive material exceeding 1 A_2 in a week

Review objective – verify that the package design satisfies the containment requirements of 10CFR71 under normal conditions of transport and hypothetical accident conditions.

Containment Review

SAR reviewed for adequacy of the description and evaluation of the containment design (Chapter 4)

- **Description of the Containment System**
  - **Containment boundary – described sufficiently for evaluation, figures, drawings, tables, welds, seals, lids, cover plates, valves, and other closure devices**
  - **Codes and standards – designed and constructed to ASME B&PVC, leak tested per ANSI N14.5**
  - **Special requirements for damaged spent fuel**
  - **Closed securely by a positive fastening device**
  - **No significant chemical, galvanic, or other reaction**
  - **Valves or similar device protected against unauthorized operation except for pressure relief valve**

Containment Review

- Normal Conditions of Transport
  - Pressurization of containment vessel
  - Combustible gases not to exceed 5% of free gas volume
  - Meets containment criteria under NCT, no filters or mechanical cooling system, no continuous venting
  - Compliance with containment criteria
  - Identify allowable normal conditions of transport volumetric leakage rates with ANSI N14.5

Containment Review

- Hypothetical Accident Conditions
  - Pressurization of the containment vessel
  - Combustible gases not to exceed 5% of the free gas volume while containment vessel is sealed.
  - Meets containment criteria
  - Compliance with containment criteria
  - Identify allowable hypothetical accident conditions volumetric leakage rates with ANSI N14.5

Review ANSI N14.5, American National Standard for Leakage Test on Packages for Shipment

- In the U.S., the 1997 edition is used
- Review document

Containment Evaluation of Type A Cask for Non-Spent Fuel

- Calculate A_2 for a mixture of releasable materials (contents) using

$$A_2 = \frac{1}{\sum \frac{f(i)}{A_2(i)}}$$

where f(i) is the releasable activity fraction of radionuclide (i)

- For Type A package, the contents must be less than an A_2 quantity
- No leak test is required

Containment Evaluation of Spent Fuel Dry Storage System

- Use NUREG-1567 “Standard Review Plan for Spent Fuel Storage”
- If dry storage cask has lids that are defined as “leak tight”, use ANSI N-14.7-1977, “American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials.”

Leak Testing of Spent Fuel Cask

- Use ANSI N14.5, American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials
- Review test procedure for helium leak testing of spent fuel cask
- Review test procedure for pressure change leak testing of spent fuel cask for preshipment leak rate testing

Leak Testing of Non-Spent Fuel Cask

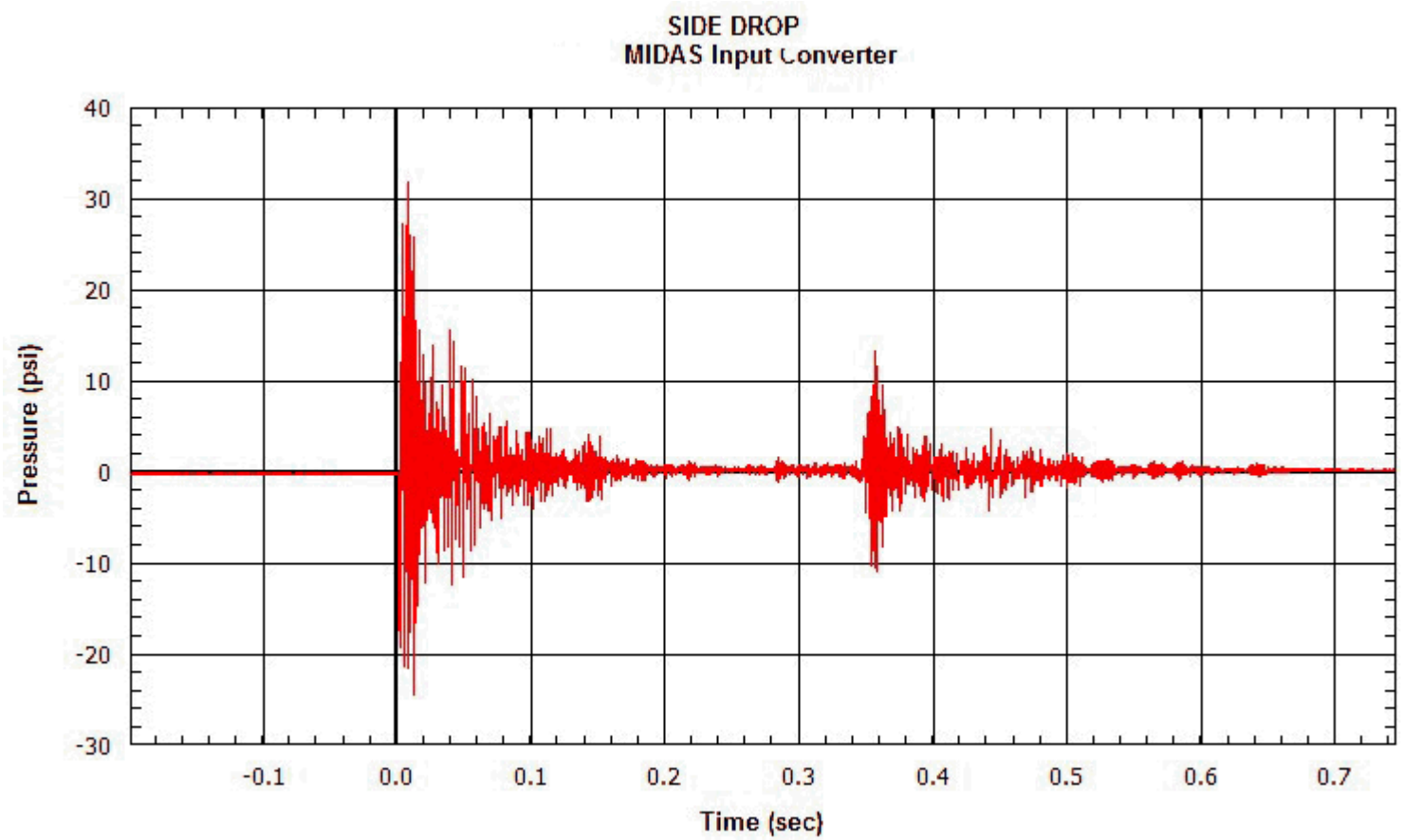
- For Type B packages, same procedures can be used for leak testing of non-spent fuel casks
- No leakage testing is necessary for Type A packages

Real Time Leak Testing at Drop Test

In our experience,

- Real time helium leak testing of packages during the drop test is not possible. For O-ring elastomers, permeation is likely to occur and will invalidate the reading.
- Monitoring pressure with a pressure transducer is possible during the drop test, see example
- Monitoring of tension in closure bolts using Superbolts is possible during the drop test, see example

Pressure Monitoring During Drop Test



- **A pressure loss of 0.4 psi was observed (original was 2 atm) after side drop**

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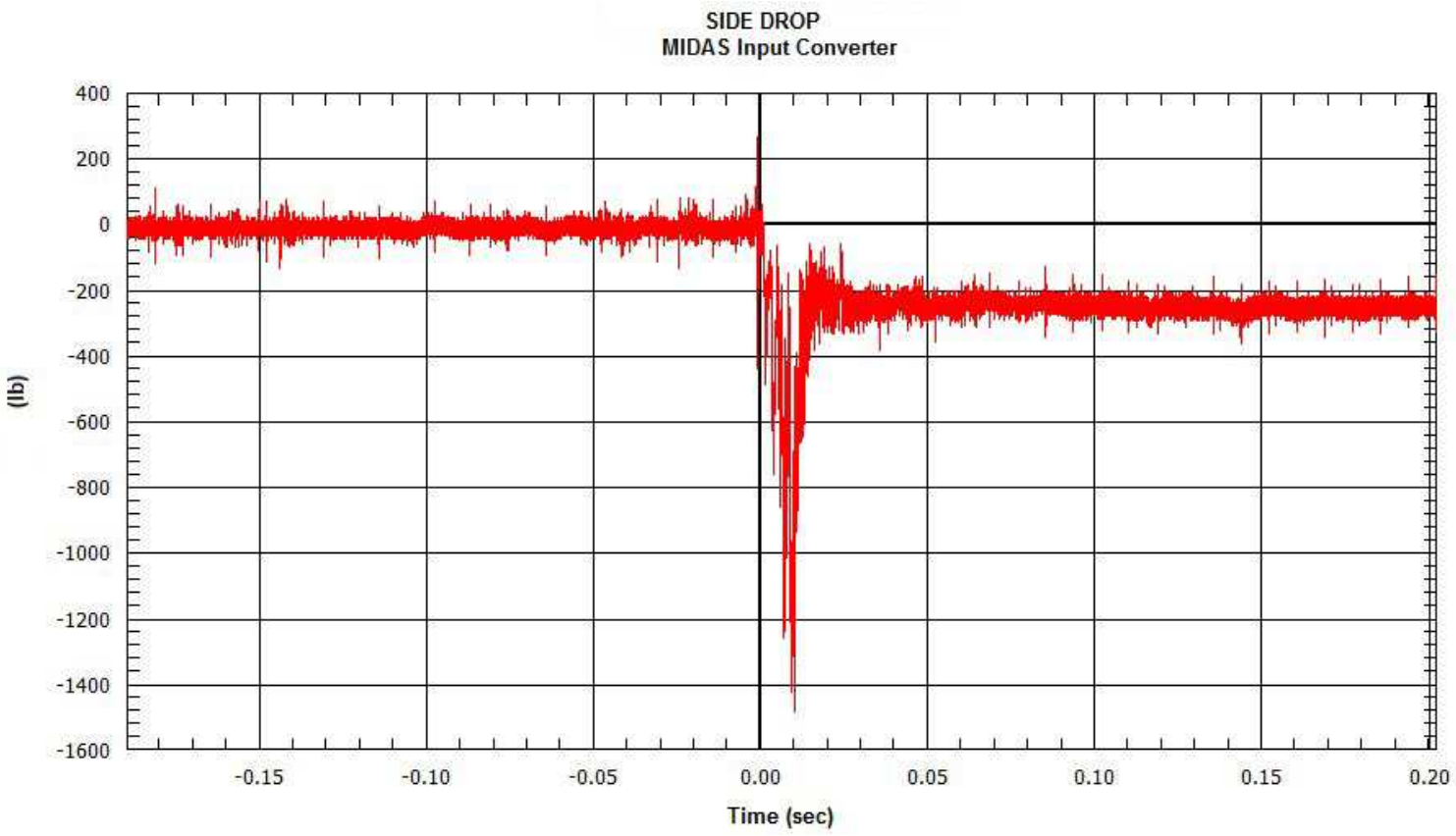
Force in Closure Bolt



- **For the Superbolt (12 jack screws), an 8500 lb preload was applied. Loss in force after the side drop test was 250 lb.**

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