# *Research Needs for Extended Storage of Used Nuclear Fuel: Container and Overpack*

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# Introduction

- Dry Storage of Used Nuclear Fuel is currently licensed for 20 years.
- Some 40 year extensions have been granted.
- Need to provide technical basis for extended storage.

# Focus for FY11

- $UO_x$ Light Water Reactor Fuels
- Impact of Normal and Off Normal Conditions
- Degradation that is influenced by extended storage times or higher burnup fuel
- Prioritization of New Research and Development

# Structures, Systems and Components (SSCs) of an Independent Spent Fuel Storage Installation (ISFSI)

1. $UO_x$ Fuel
2. Cladding
3. Fuel Assembly Hardware
4. Fuel Baskets
5. Neutron Poisons
6. Neutron Shields
7. Container *
8. Overpack or Storage Module *
9. Pad
10. Monitoring Systems

# Dry Cask Storage Systems:

## Two Types:

- *Bolted, Direct Load Metal Casks*
  - Typically thick walled carbon or low alloy steel containers
  - Can be transportable if basket has neutron poisons
- *Welded Canisters with Overpacks*
  - More recent designs
  - Typically a stainless steel container within a reinforced concrete storage overpack
  - Can be transportable with another overpack if basket has neutron poisons

# Dry Cask Storage Systems: Bolted Metal Casks

## Common Features

- Multi layered Casks with Integral:
  - Fuel Baskets
    - **Optional Neutron Poisons**
  - Confinement Container
  - Metal Overpack
    - **Neutron Shields**
- Separate Cover for Seals and Bolts

## 170 in Use in 2011*

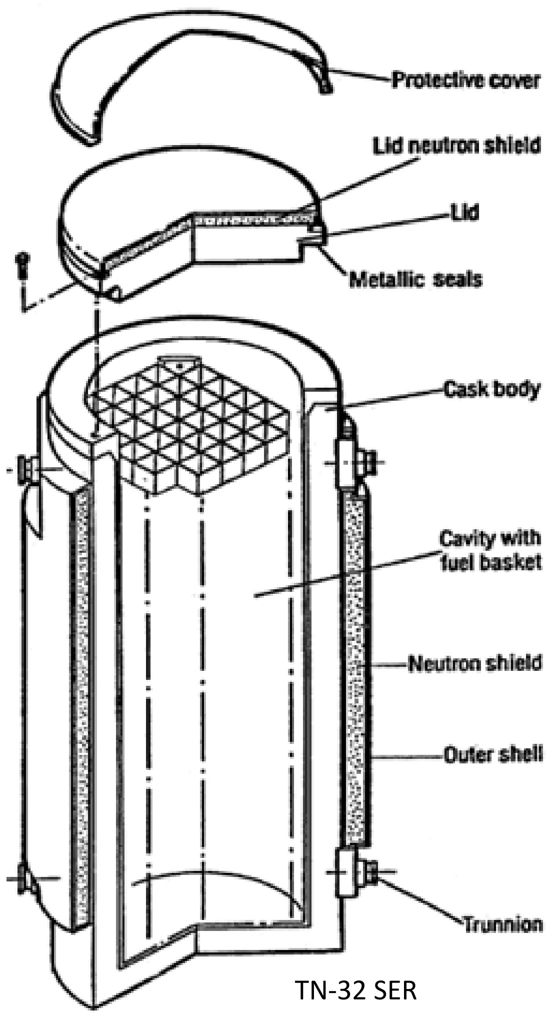
- 1 MC-10
- 2 NAC I28
- 26 Castor V21, X33
- 141 TN 32, 40, 68

* StoreFUEL March 2011

Red = recent

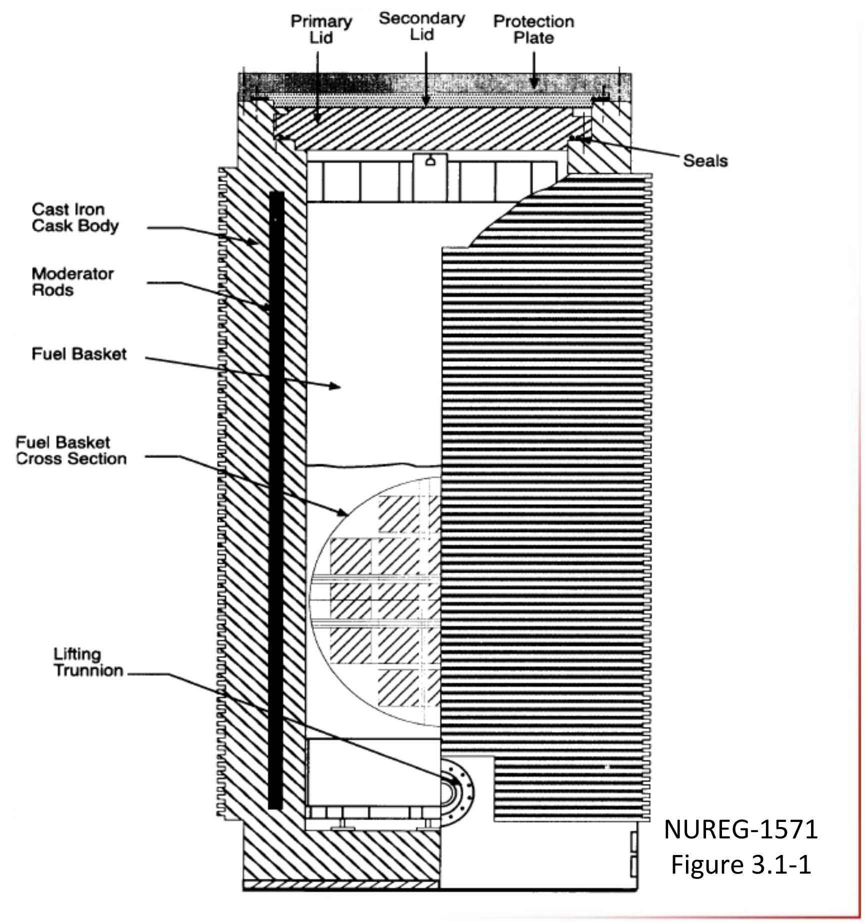
# Dry Cask Storage Systems: Bolted Metal Casks

## Transnuclear TN-32




TN-32 SER

## Castor V/21




NUREG-1571
Figure 3.1-1

# Dry Cask Storage Systems: Welded Metal Canisters with Overpacks

## Common Features

- Multipurpose Canister with Integral:
  - Fuel baskets holding optional neutron poisons
  - Confinement Container
- Separate Transfer Cask and Overpack or Storage Module
  - Neutron Shielding

Red = recent

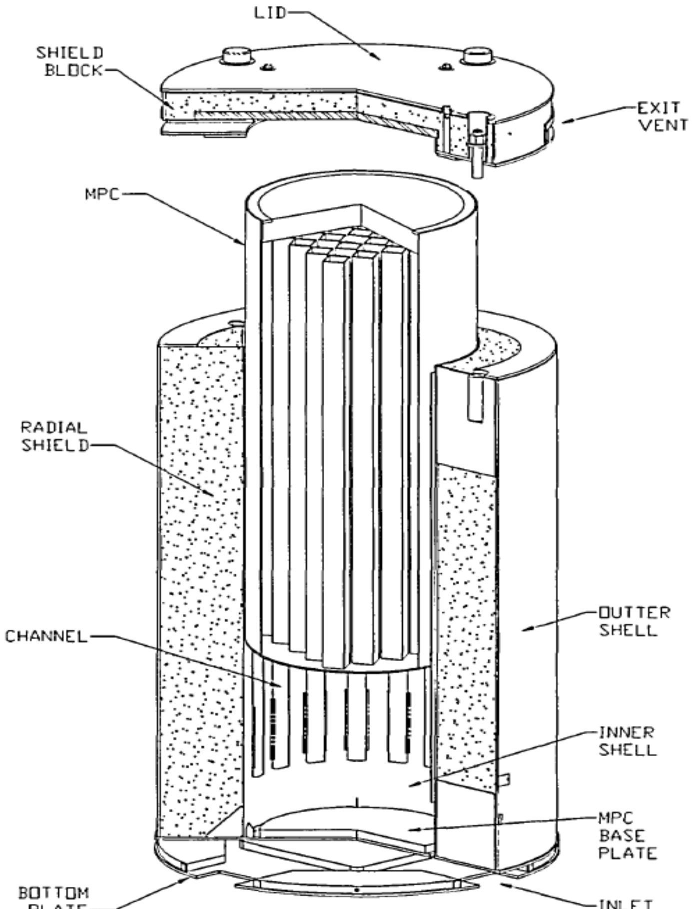
## 1234 in Use in 2011*

- 8 W150
- 12 HI-STAR
- 34 TranStor
- 58 VSC-24
- 246 NAC UMS-24, MPC-26 and 36
- 347 HI-STORM
- 529 NUHOMS

* StoreFUEL March 2011

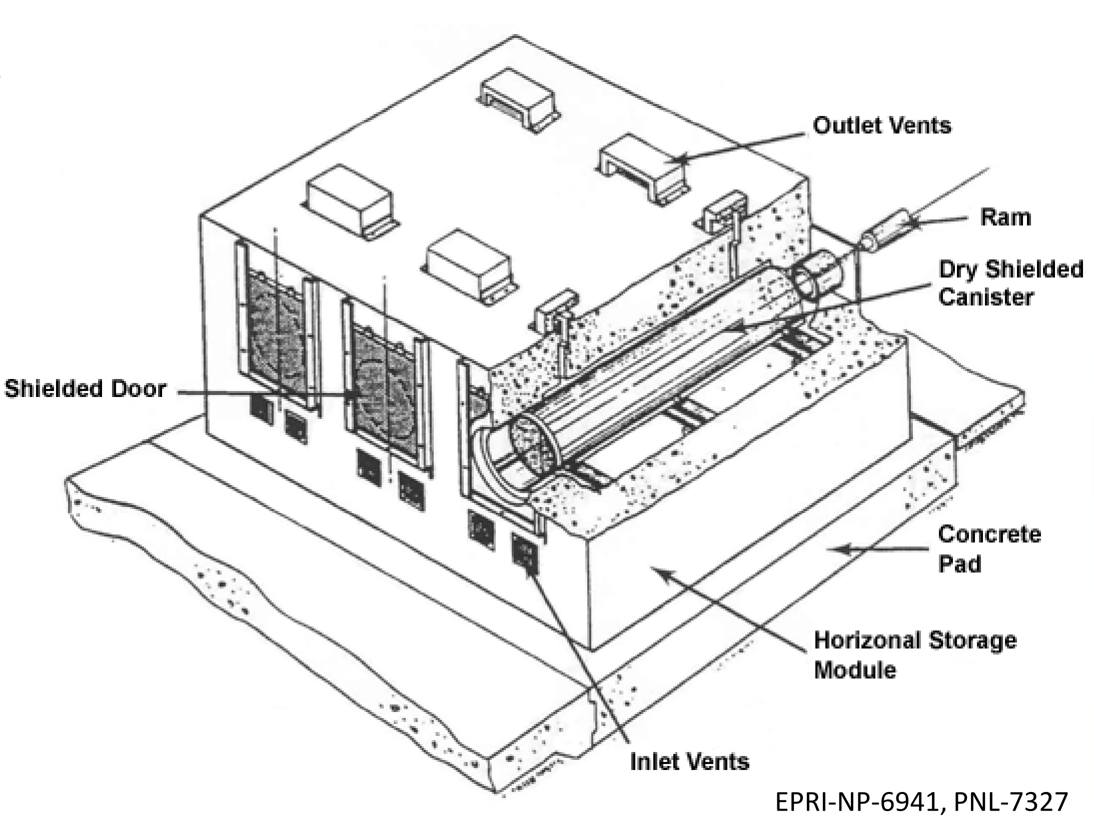
# Dry Cask Storage Systems: Welded Metal Canisters with Overpacks

## HI-STORM



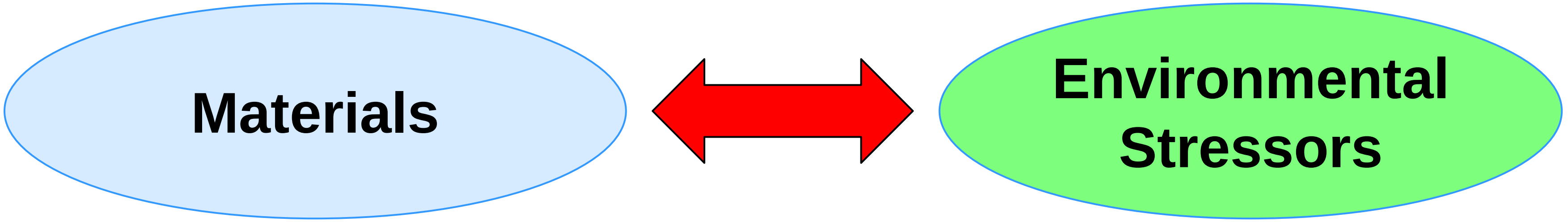

HI-STORM 100 FSAR Rev2.

## NUHOMS



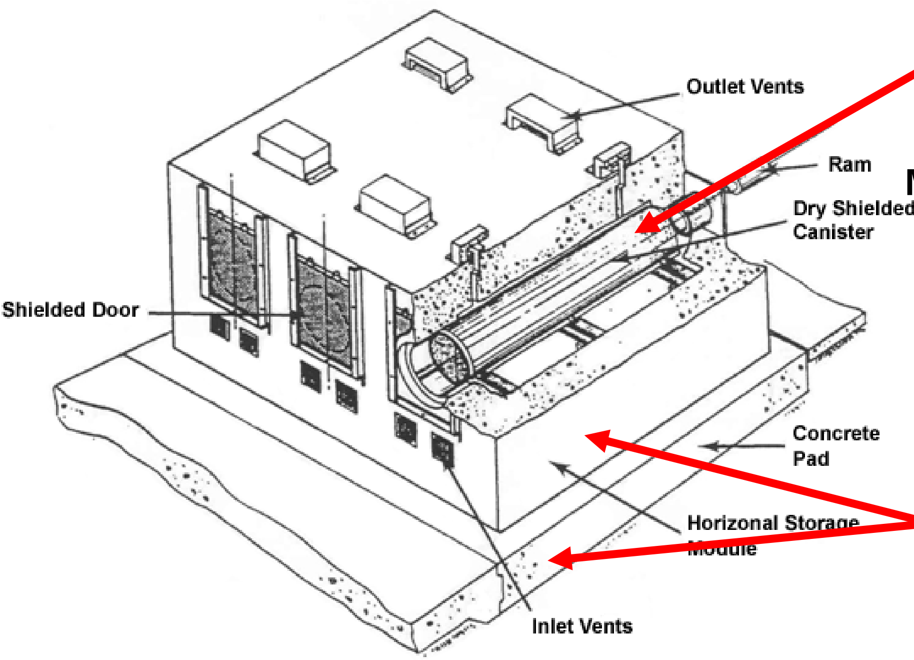

EPRI-NP-6941, PNL-7327

# Degradation Mechanisms

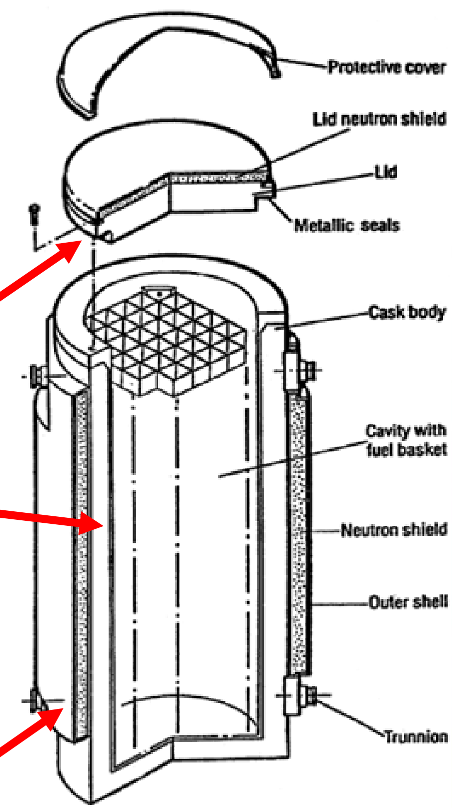


# Typical Materials of Construction

## Welded (e.g., NUHOMS)




## Bolted (e.g., TN-32)




**Stainless Steel**

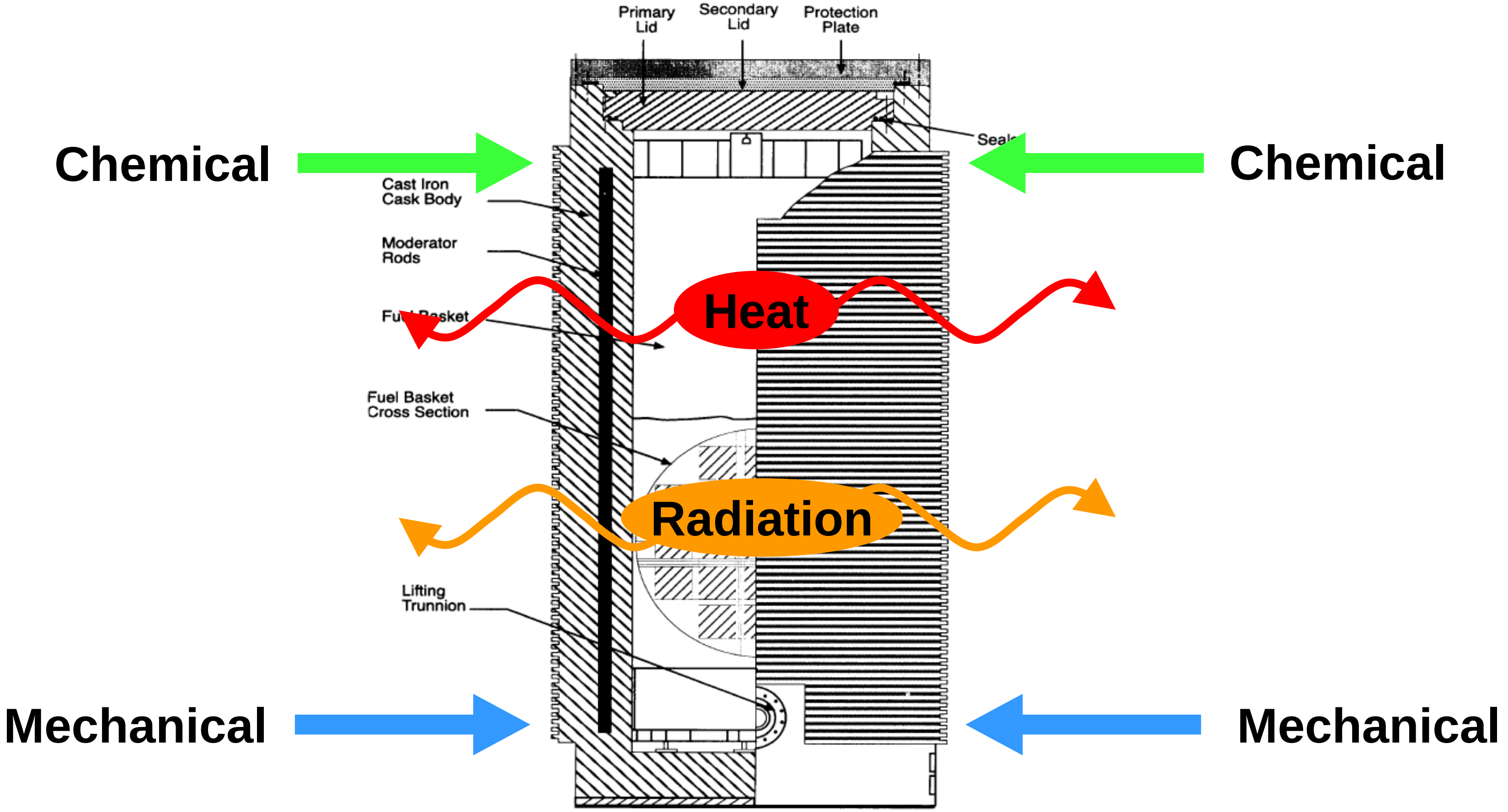
**Metal and Polymer O-rings**

**Carbon Steel**

**Reinforced Concrete**

**Polymeric Material**

# Environmental Stressors



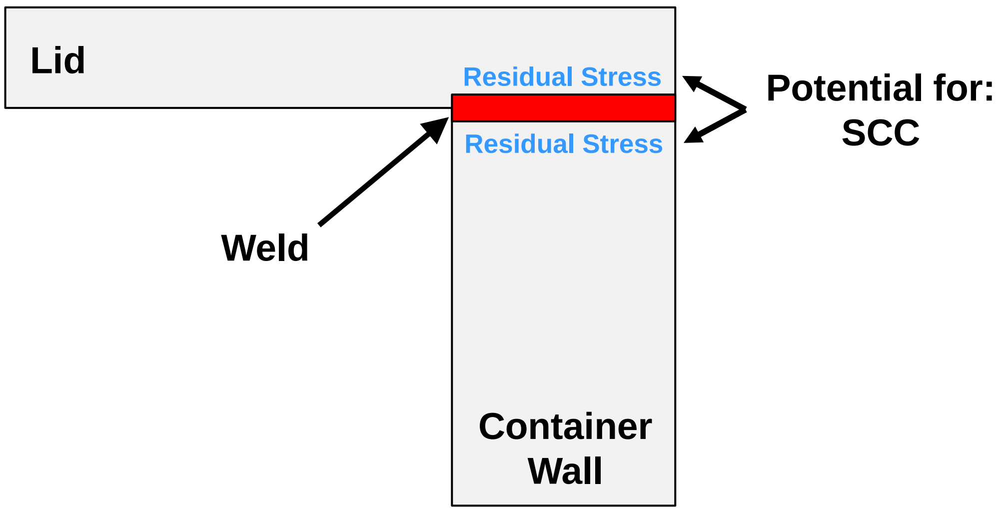
# Container and Overpack: Priority of New Research and Development

- **Do we have sufficient data?**
  - Large amount of data on steels and concretes
  - ISFSI Safety analysis Reports (SARs) discuss environment for 20 years
  - Thermal history needed for long term storage
- **Probability of degradation mechanism occurring?**
  - Depends on material and environment
  - Probability of loss of safety functions is low in license period
- **Consequence of degradation?**
  - Container breach – Release of Radionuclides
  - Concrete degradation – Temporary loss of protection for container
- **Aging management program?**
  - Difficult for internal components such as seals, and canisters
  - Easier for external components such as overpacks or storage modules

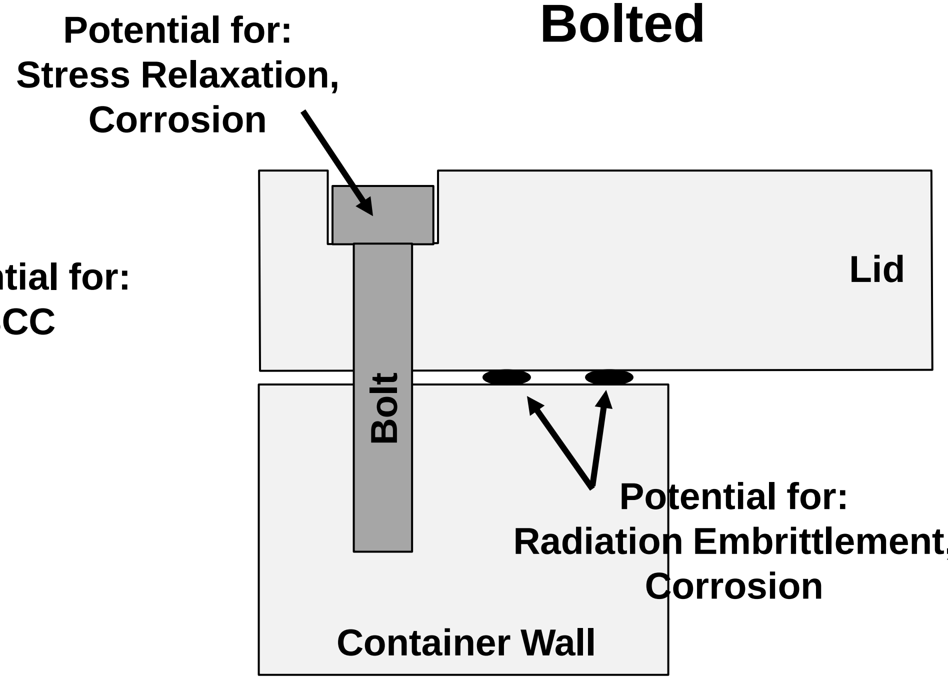
# Degradation of Closures

- Maintaining waste confinement is required
- The closure system is generally the weakest link
- Must protect from corrosive environment

## Welded




## Bolted



# Corrosion of Closure Welds, Bolts, and Seals

- **Atmospheric Corrosion**
  - High humidity plus aggressive contamination (gaseous or solid phase)
  - SCC could initiate at closure welds and bolts since no stress mitigation is performed
  - Due to potential impact of SCC, research priority is high

- **Aqueous Corrosion**
  - Protective cover may leak
  - Once fuel has cooled, condensation may form on container surface – this combined with aggressive contamination could potentially lead to corrosion initiation on container.
  - Primarily an issue for non-stainless steel containers
  - Due to potential impact of general corrosion on carbon steel container designs, research priority is high

# Container Degradation Mechanisms Base Metal, Welds, Bolts, and Seals

| Stressor | Degradation Mechanism | Influenced by VLTS or Higher Burnup | Additional Data Needed | Priority of R&D |
|---|---|---|---|---|
| Thermal and Mechanical | Embrittlement of elastomer seals | Yes | Yes | Low |
| | Thermomechanical fatigue of seals and bolts | Yes | Yes | Medium |
| Radiation | Embrittlement of elastomer seals | Yes | Yes | Low |
| Chemical | Atmospheric Corrosion (Including Marine Environment) | Yes | Yes | High |
| | Aqueous Corrosion: general, localized (pitting, crevice), SCC, galvanic | Yes | Yes | High |

# Concrete Overpack Degradation Mechanisms

| Stressor | Degradation Mechanism | Influenced by VLTS or Higher Burnup | Additional Data Needed | Priority of R&D |
|---|---|---|---|---|
| Thermal | Dry Out | Yes | Yes | Low |
| | Freeze Thaw | Yes | Yes | Low |
| Radiation | Aggregate Growth | Yes | Yes | Low |
| | Decomposition of Water | Yes | Yes | Low |
| Chemical | Calcium leaching | Yes | Yes | Low |
| | Chemical Attack | Yes | Yes | Low |
| | Chemical Reaction with Aggregate | Yes | Yes | Low |
| | Corrosion of Embedded Steel | Yes | Yes | Low |
| Mechanical | Creep | Yes | No | Low |

# Concluding Remarks

## Defining New Research and Development

- **Near Term Research**
  - Evaluation of long term environment for canisters
  - Longer-term aging management programs
- **Testing and Evaluation Facility (TEF)**
  - Monitor Container and Overpack for any form of degradation that may jeopardize their ability to perform their safety functions

# BACKUP SLIDES

# Container Degradation Mechanisms: Bolted Canisters

- **Thermal/mechanical, and radiation stressors may impact seal integrity**

- **Thermal and mechanical stressors**
  - Thermal exposure for extended periods of time may embrittle elastomeric seals
    - As these are secondary seals, research priority is low
  - Thermal cycling may result in fatigue of bolts used to secure lids
    - Due to potential impact to casks, research priority is medium

- **Radiation exposure**
  - Prolonged exposure to radiation fields may result in the embrittlement of elastomeric seals.
  - As these are always secondary seals, research priority is low

# Degradation Mechanisms: Overpack

- **The integrity of the overpack does not directly impact containment, and degradation may be identified and repaired, priority of new research is low**
- **Thermal effects**
  - Exposure to temperatures above 150F results in dehydration of concrete, lowering strength
  - Freeze-Thaw exposure can result in a mechanical stress sufficient to crack concrete
- **Radiation effects**
  - Exposure to high levels of neutrons can result in aggregate growth, the decomposition of water within the pore structure of the concrete, and thermal warming of the concrete.
  - Reactions can result in a loss of strength of the concrete
- **Chemical effects**
  - Corrosion of the reinforcement can result in strength loss and cracking
  - Aggregate within the concrete can react with alkali species within the concrete (alkali-silica reaction, cement-aggregate reaction, alkali-carbonate reaction), potentially causing significant cracking/structural damage.
  - Calcium hydroxide may be leached from the concrete, reducing the pore water pH, and potentially causing corrosion of the reinforcing steel