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Aging Effects on Structural Concrete and Long-term Storage of Spent Nuclear Fuel in DCSS at ISFSIs in the USA

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OUTLINE

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- DCSS – Safety Functions
- Basic Orientation of DCSS
- Concrete Durability & Deterioration
- Mechanisms & Effects of Concrete Aging
- Acceptance Criteria
- Summary
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DCSS - Safety Functions

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- **Dry Cask Storage System (DCSS)** is designed and built to comply with 10 CFR Part 72 regulations
- **Safety Functions**
  - Structural/Material integrity
    - Withstand external natural phenomena hazard (NPH) events
    - Robustness against severe man-made events
  - Radiological Shielding and Criticality Control
  - Heat Transfer
- **Technical Challenge** is to maintain intended design safety functions for:
  - Initial license (20 Yrs.)
  - Renewal license (First Renewal up to 40 Yrs.)
  - Extended Storage - Long-term (a period of up to 300 years)

Two Basic Orientation of DCSS

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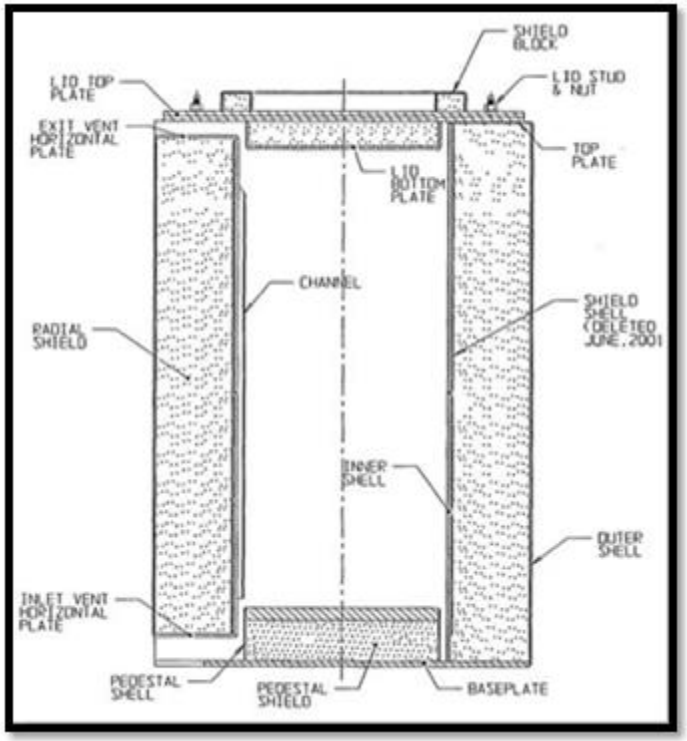
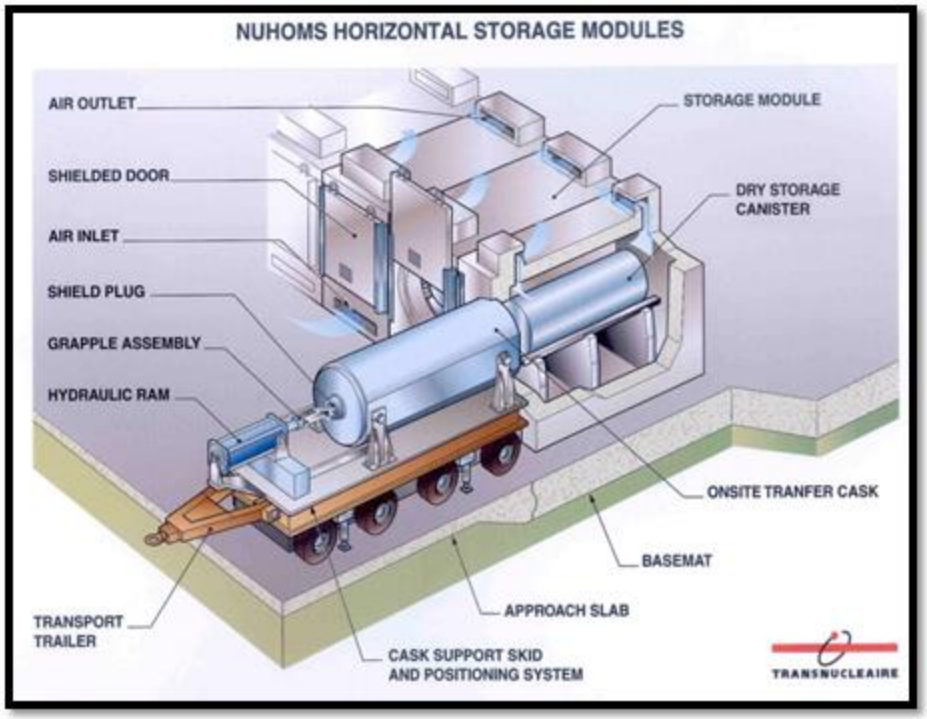


Vertical DCSS



Horizontal DCSS

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Concrete Durability

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- American Concrete Institute (ACI) Committee 201 (2008) defines durability of Portland cement concrete as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration
- Durable concrete will retain its original form, quality, and serviceability when exposed to its envisioned environment

Mechanisms & Effects of Concrete Aging

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Mechanism	Effects
Freeze-thaw	Cracking, loss of material (spalling, scaling)
Chemical attack [Cl, SO_4]	Cracking, loss of material (spalling, scaling)
Aggregate reactions/expansion	Cracking and loss of strength
Corrosion of embedded steel	Cracking, loss of material (spalling, scaling) and loss of bond
Leaching of $Ca(OH)_2$ → $Ca(CO)_3$	Increase in porosity/permeability, loss of strength
Settlement (short & long-term)	Cracking, distortion
Gamma irradiation	Cracking, reduction in strength (change in mechanical properties)
High temperature dehydration	Cracking, reduction in strength (change in mechanical properties)

Concrete Deterioration

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- No structural material is indefinitely durable; as a result of environmental interactions, the microstructure, and consequently the properties of materials change with time
- Concrete structures are generally designed for a service life of 50 years, but experience shows that in urban and coastal environments many structures begin to deteriorate in 20 to 30 years or even less time

Other Mechanisms Affecting Concrete

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- Deterioration can occur by:
  - ✓Surface wear by Abrasion: dry attrition (wear on concrete pad)
  - ✓Erosion: wear produced by abrasive action of fluids containing solid particles in suspension (inside the storage module)

Other Mechanisms affecting Concrete Contd..

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- ✓Cavitation: loss of mass by formation of vapor bubbles and their subsequent collapse (e.g. inside the horizontal storage module)
- ✓Frost action “Freeze-Thaw”
- ✓Salt scaling and crystallization, aggressive ion (e.g. H^{+} or Mg^{++}) attack

Concrete Degradation Due to Sulfur

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- The presence of sulfuric acid on concrete leads to concrete disintegration
- The growth of seaweed may also create a problem, if the seaweed is exposed at low tide

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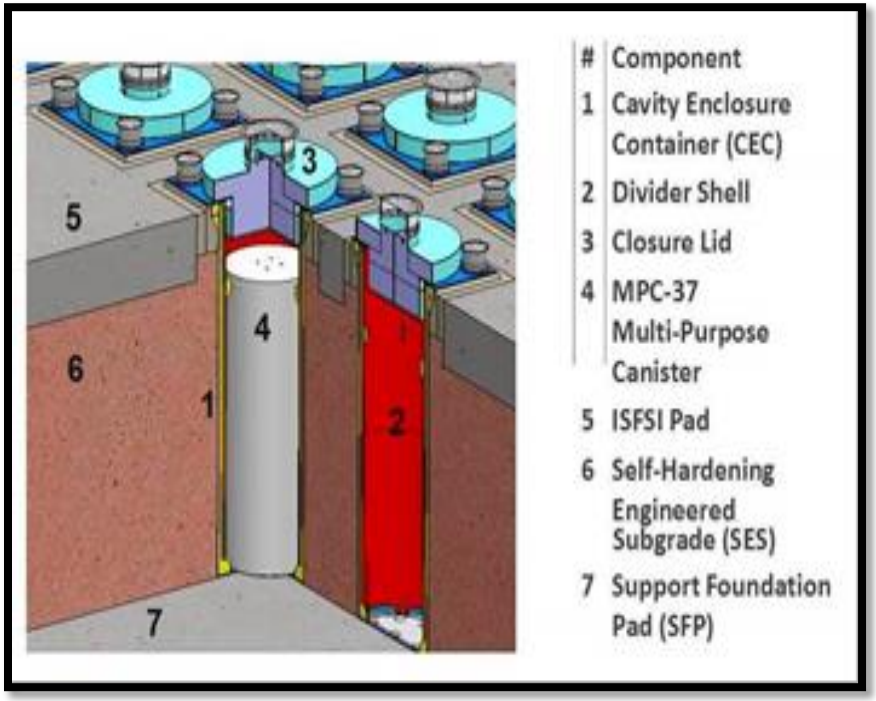
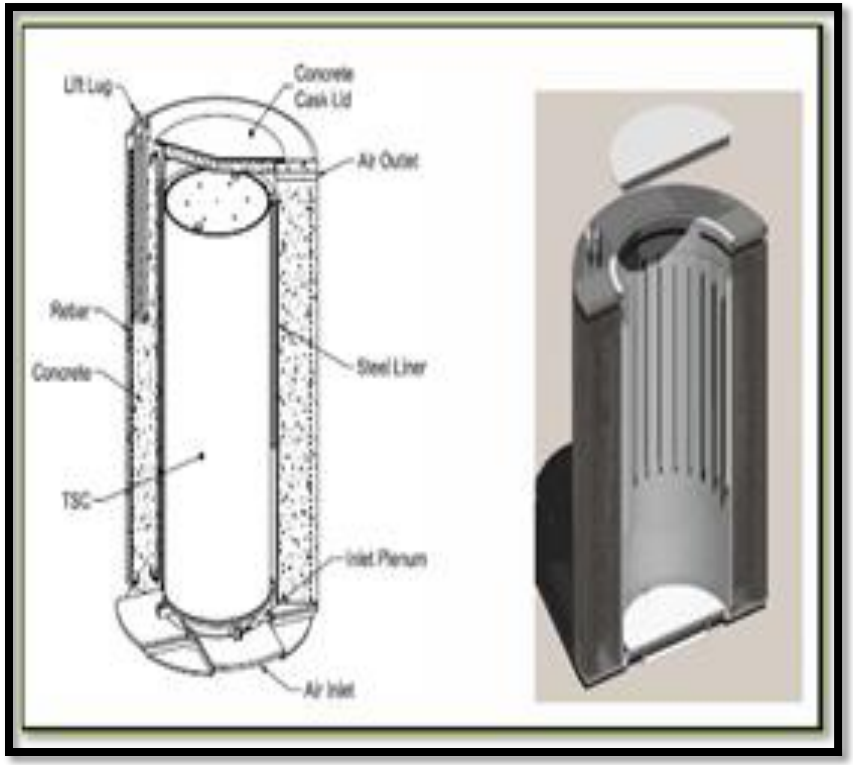
Variety of Storage Systems



HOLTEC - UMAX Systems [Version MSE]



MAGNASTOR Systems

Acceptance Criteria

- ACI-349 – 3R
- ASTM Specifications
- NRC NUREG 1927 Rev. 1
- NEI 14-07

Summary

- The functionality of the degraded structural system is dependent on the structural configuration, environment, and operating conditions
- The regulator [U.S. NRC], and nuclear industry are reviewing the potential degradation mechanisms
- The aging management program addresses these reviews to comply with the design bases and the required safety functions of the DCSS, and thereby protecting public health and safety

Conclusions

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- In evaluating component and system aging, the NRC staff analyzes for period that extends from initial licensing of 20 years and renewal of up to 40 years of dry storage
- This is reflected in the staff's approach for time-limited aging analysis
- Within the extended storage of SNF regulatory program, the aging of systems and components may have to be viewed as occurring on a continuum that extends from initial licensing and renewal, through longer periods (up to 300 years) of extended storage

QUESTIONS ?

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