

**Protecting People and the Environment** 

# Generic Concrete Aging Management Program

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Meeting to Obtain Stakeholder Input on Potential Changes to Guidance for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance

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- Valid basis include applicable consensus codes/standards and/or NUREG guidance, e.g.:
  - ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures"
  - ASME Code Section XI, Subsection IWL, "Requirements for Class CC Concrete Components of Light-Water-Cooled Plants"
  - NUREG-1801, "Generic Aging Lessons Learned (GALL) Report"

## Applicant may propose AMPs based on alternate criteria:

- Exclusion of aging effects/mechanisms in the above codes/standards should be justified with a site-specific technical basis (e.g., engineering analysis, operational experience data).
- Justification should demonstrate that the excluded aging mechanisms will not adversely affect the ability of the in-scope structure to perform its intended function during the license period of extended operation.

# **Aging Effects/Mechanisms**



Mechanism	Effect
Freeze-thaw	Cracking, loss of material (spalling, scaling)
Chemical attack [CI, SO <sub>4</sub> ]	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) <sub>2</sub> $\rightarrow$ CaCO <sub>3</sub>	Increase in porosity/permeability, loss of strength
Long-term settlement	Cracking, distortion
Gamma/neutron irradiation	Cracking, reduction in strength (change in mechanical properties)
High temperature dehydration	Cracking, reduction in strength (change in mechanical properties)

## Not necessarily all-inclusive



## Irradiation/ Thermal Dehydration

- Reductions in strength and elastic modulus not managed by this AMP visual examination not sufficient
- TLAA may be used to demonstrate that no part of the concrete exceeds:
  - <u>Critical cumulative fluences per ACI 349.3R</u>: 10<sup>17</sup> neutrons/m<sup>2</sup>; 10<sup>10</sup> rad (gamma dose)
  - <u>Temperature limits per ACI 349</u>: 150°C (general), 200°C (localized)

## "Change in Materials Properties"

- Definition per either ASTM C1562 or EPRI 1002950<sup>\*</sup> not implicit, i.e.:
  - increases in permeability and porosity
  - reduction in pH value, tensile strength, compressive strength, modulus of elasticity, and bond strength
- Reference to this "aging effect" must include proper definition in the LRA

## AMP Element 1: Scope of the Program



**NUREG-1927:** The scope of the program should include the specific structures and components subject to an aging management review

- 1. <u>Visual inspection</u> of all above-grade (accessible, inaccessible) and below-grade (underground) concrete areas
  - ACI 349.3R: "All safety-related structures should be visually inspected at intervals not to exceed 10 years"
- 2. <u>Groundwater chemistry program</u> to manage below-grade (underground) effects
  - Corrosion of embedded steel
  - Chemical attack (chloride, sulfate induced degradation)

## 3. <u>Periodic radiation surveys</u>

- <u>Controlled Area:</u> Compliance with 10 CFR 72.104.
- <u>Near cask (e.g. 1m)</u>: Monitor effectiveness as neutron shield (i.e. dose uptrends); FSAR validation at specific locations

## AMP Element 2: **Preventive Actions**



# **NUREG-1927:** Preventive actions should mitigate or prevent the applicable aging effects

- Program is for <u>Condition Monitoring</u>
- Design in accordance to **ACI 318 or ACI 349**, as applicable.

### Otherwise,

- For locations in moderate (100-500 day-inch/yr) and severe (>500 day-inch/yr) weathering conditions, concrete mix design must meet air content & water-to-cement ratio requirements of ASTM C260 or ASME Sect. III, Div. 2.
- Petrographic examination (ASTM C295 or equivalent) must demonstrate reactive aggregates do not lead to loss of function.
- Site-specific AMP required if:
  - Dewatering system used to prevent long-term settlement
  - Embedded aluminum components without protective insulating coating

## AMP Element 3: Parameters Monitored/ Inspected



**NUREG-1927:** Parameters monitored or inspected should be linked to the effects of aging on the intended functions of the particular structure and component

- Quantify effects including cracking, material loss (spalling, scaling), loss of bond, increased porosity/permeability.
- ACI 201.1R and SEI ASCE 11-99: exemplary visuals of effects.
- Evaluation should identify, e.g.
  - affected surface area
  - geometry/depth of defect
  - cracking, crazing, curling
  - delaminations, deflections
  - honeycombing, bug holes

- popouts, voids
- exposure of embedded steel
- staining/ evidence of corrosion
- dusting, efflorescence of any color
- Contributing factors should be evaluated/documented, e.g.:
  - surface geometry supporting ponding, lack of air entrainment
  - widening due to abrasion/ other weather effects

## AMP Element 4: Detection of Aging Effects



**NUREG-1927:** Define method or technique, frequency, sample size, data collection, and timing to ensure timely detection of aging effects

- Method/technique (meet criteria in ACI 349.3R/ IWL-2512)
  - AMP must include justification that the technique can achieve the acceptance criteria; reference valid calibration methods and frequency.
  - ABOVE-GRADE (accessible): visual (e.g., feeler gauges, crack comparators)
  - ABOVE-GRADE (inaccessible)/ BELOW-GRADE (underground)
    - Visual: site-qualified system with valid sensitivity/resolution (e.g., video/ fiber optic camera)
    - Ground water monitoring program: qualified chemical analysis method
    - Radiation surveys: calibrated detector, valid energy range
- <u>Frequency of Inspection</u> (commensurate with ACI 349.3R)
  - ABOVE-GRADE (accessible and inaccessible): ≤ 5 years
  - BELOW-GRADE (underground): ≤ 10 years, and when excavated for any reason
  - Use of opportunistic inspections in lieu of planned inspections must include valid technical basis (engineering justification, operational experience data).

## AMP Element 4: Detection of Aging Effects (cont.)



**NUREG-1927:** Define method or technique, frequency, sample size, data collection, and timing to ensure timely detection of aging effects

### Frequency of Inspection (cont.)

- Water chemistry program/ radiation survey measurements: justified
- Daily inspections of inlet/outlet vents to ensure ACI 349 temperature limits (or technical specifications) are not exceeded.

### Sample size:

- All surface areas as stated in scope, or justified size
- Clearly identify and justify specific locations (specify accessible or inaccessible)

### Data collection

- Commensurate with applicable standards: e.g. ACI 224.1R for quantitative analysis (width, depth, extent), ACI 562, ACI 364.1R.
- Reference adequate clearinghouse for Operating Experience
- Timing
  - Lead canister inspection / frequency specified by AMP
  - Inspection frequencies may be accelerated per site CAP

## AMP Element 5: Monitoring & Trending



**NUREG-1927:** Should provide for prediction of the extent of the effects of aging and timely corrective or mitigative actions

### • <u>Commensurate with:</u>

- Defect evaluation standards (e.g. ACI 201.1R, ACI 207.3R, ACI 364.1R, ACI 562, ACI 224.1R crack evaluation)
- Acceptance criteria and inspector qualifications (e.g., ACI 349.3R, ASME Code Section XI)
- <u>AMP should reference plans/procedures used to:</u>
  - Establish a baseline prior to or at the beginning of the renewal period
  - Track trending of parameter, or effect not corrected in a previous inspection, e.g.:
    - Crack growth rates
    - Corrosion rates
    - Pore density/ affected areas
    - Dose rates

## AMP Element 6: **Acceptance Criteria**



**NUREG-1927:** Acceptance criteria, against which the need for corrective action will be evaluated: should ensure that SSC functions are maintained

#### *Visual:* Commensurate with ACI 349.3R (3-Tier Quantitative Criteria):

- Acceptance without further evaluation
- Acceptance after review
- Acceptance requiring further evaluation

#### Groundwater Chemistry Program: ASME Code Section XI, NUREG-1801

Aggressive below-grade environment: pH < 5.5, chlorides > 500 ppm, or sulfates > 1500 ppm

### **Radiation Surveys**

- Controlled area: 10 CFR 72.104 (bounding limit)
- Near cask (e.g., 1 m): A statistically significant uptrend in neutron dose rate, justified criteria (e.g. moving average)

#### Alternative acceptance criteria may be provided, but must:

- Include a quantitative basis (justifiable by OE, engineering analysis/standards)
- Avoid use of non quantifiable phrases (e.g. significant, moderate, minor, little, slight, few, etc.)
- Be achievable and clearly actionable Method/technique must be qualified to meet the stated quantitative criteria (i.e. sufficient resolution/sensitivity)

## AMP Element 7: Corrective Actions



**NUREG-1927:** Corrective actions, including root cause determination and prevention of recurrence, should be timely

- CAP commensurate with 10 CFR 72 Subpart G, or 10 CFR 50 Appendix B.
  - Justification for non-repairs (e.g., engineering analysis)
- AMP should reference applicable concrete rehabilitation standards.
  - Cracking: ACI 224.1R, ACI 562, ACI 364.1R, and ACI RAP Bulletins
  - Spalling/scaling: ACI 562, ACI 364.1R, ACI 506R, and ACI RAP Bulletins
- AMP should reference criteria used to determine which inspection results will require either:
  - An Action Request (e.g, Tier 2 Acceptance per ACI 349.3R)
  - Modification to the existing AMP (e.g. increased frequency)
  - Notification to the NRC (e.g., Tier 3 Acceptance per ACI 349.3R)
- AMP should reference how industry-wide OE will lead to any of the above action items

## AMP Elements 8/9: Confirmation Process/Admin Controls



### NUREG-1927:

- The confirmation process should ensure that preventive actions are adequate and appropriate corrective actions have been completed and are effective
- Administrative controls should provide a formal review and approval process

### **Elements should reference:**

- Quality Assurance Program consistent with 10 CFR 72 Subpart G, or 10 CFR 50 Appendix B.
- Methods to confirm adequate actions are taken, and are verified as effective
- Inspector qualifications
  - Commensurate with ACI 349.3R
- Record retention requirements
- Review process of inspection results
- Frequency/methods for:
  - reporting inspection results to NRC
  - evaluating suitability of AMP based on industry-wide OE

## AMP Element 10: Operating Experience



**NUREG-1927:** Include past corrective actions; provide objective evidence to support a determination that the effects of aging will be adequately managed so that the SSC intended functions will be maintained during the period of extended operation

### **Reference and evaluate applicable OE:**

- Internal and industry-wide CRs
  - Identify age-related degradation
    - Include justification for CRs not identified as age-related degradation
  - <u>Consider CARs when proposing:</u>
    - Method/technique, acceptance criteria, frequency of inspection
- NRC Information Notices
- Applicable industry initiatives (e.g. DOE cask demo, EPRI-sponsored inspections)
- OE presented in LRA should support the proposed AMP

### **Reference OE clearinghouse**

- INPO or other adequate system
- Methods for capturing and evaluating operating experience from other ISFSIs with similar in-scope SSCs.



## **Additional Slides**



## NUREG-1536 (SRP Spent Fuel Dry Storage Systems/ General License)

### Section 6.5.4.3 – Dose Rates

### Guidance for the selection of points at which the dose rates should be calculated.

- For normal and off-normal conditions, applicant should indicate the dose rate at all locations accessible to occupational personnel during <u>cask loading</u>, <u>transport to the</u> <u>ISFSI</u>, and <u>maintenance and surveillance operations</u>.
  - Locations include points at or near various cask components and in the immediate vicinity of the cask and the bottom of the transfer cask.
    - e.g.: vent areas, trunnion areas, peak side of the cask, peak top of the cask, the canister-gap region
  - Calculate dose rates at <u>1m from these locations</u>.

### NUREG 1567 (SRP Spent Fuel Dry Storage Facilities)

### Section 11.4.3 – Dose Assessment

 Estimated dose rates should be provided for <u>representative points</u> within the restricted areas as well as on and beyond the perimeter of the controlled area.

## Acronyms



- ACI: American Concrete Institute
- AMP: Aging Management Program
- ASCE: American Society of Civil Engineers
- ASME: American Society of Mechanical Engineers
- ASTM: American Society for Testing and Materials
- CAP: Corrective Action Program
- CAR: Corrective Action Report
- CFR: Code of Federal Regulations
- CR: Condition Report
- DOE: Department of Energy
- EPRI: Electric Power Research Institute
- FSAR: Final Safety Analysis Report
- ISFSI: Independent Spent Fuel Storage Installation
- INPO: Institute of Nuclear Power Operations
- ITS: Important to Safety
- LRA: License Renewal Application
- OE: Operating Experience
- RAP: Repair Application Procedure
- SEI: Structural Engineering Institute
- SRP: Standard Review Plan
- SSC: Structure, System, or Component
- TLAA: Time-Limited Aging Analysis