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# Generic Concrete Aging Management Program

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# Basis for Development

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- **<u>Valid basis include applicable consensus codes/standards and/or NUREG guidance</u>, 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”
- **<u>Applicant may propose AMPs based on alternate criteria:</u>**
  - 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

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| Mechanism | Effect |
|---|---|
| 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 $Ca(OH)_2 \rightarrow CaCO_3$ | 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**

# Aging Effects/Mechanisms

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## 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:
  - Critical cummulative fluences per ACI 349.3R: $10^{17}$ neutrons/$m^2$; $10^{10}$ rad (gamma dose)
  - Temperature limits per ACI 349: 150°C (general), 200°C (localized)

## "Change in Materials Properties"

- Definition per either ASTM C1562 or EPRI 1002950* **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" **should include proper definition** in the LRA

EPRI 1002950 not endorsed by SFST

## AMP Element 1:
# Scope of the Program

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

1. **Visual inspection** 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. **Groundwater chemistry program** to manage below-grade (underground) effects
   - Corrosion of embedded steel
   - Chemical attack (chloride, sulfate induced degradation)

3. **Periodic radiation surveys**
   - Controlled Area: Compliance with 10 CFR 72.104.
   - Near cask (e.g. 1m): Monitor effectiveness as neutron shield (i.e. dose uptrends); FSAR validation at specific locations

## AMP Element 2:
# Preventive Actions

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

- Program is for ***Condition Monitoring***
- 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 should meet air content & water-to-cement ratio requirements of ASTM C260 or ASME Sect. III, Div. 2.
  - Petrographic examination (ASTM C295 or equivalent) should 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

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**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

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

- **<u>Method/technique</u> (meet criteria in ACI 349.3R/ IWL-2512)**
  - ***AMP should 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 should include valid technical basis (engineering justification, operational experience data).***

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

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**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

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

- **Commensurate with:**
  - 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)

- **AMP should reference plans/procedures used to:**
  - 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

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**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 should:**
  - 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 should be qualified to meet the stated quantitative criteria (i.e. sufficient resolution/sensitivity)

# AMP Element 7:
# Corrective Actions

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**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

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**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

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**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
  - Consider CARs when proposing:
    - 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.**

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# Additional Slides

# Radiation Bounding Criteria

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## 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 cask loading, transport to the ISFSI, and maintenance and surveillance operations.
  - 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 1m from these locations.

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

### Section 11.4.3 – Dose Assessment

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

# Acronyms

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- 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