How does the use of passive safety systems impact aging management - the AP1000® plant experience

From Active Component Testing to Passive System Monitoring

Lessons from Vogtle Units 3 & 4 and China AP1000 Fleet

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01 The Paradigm Shift: Active to Passive

Conventional PWR

Active component aging management

- General aging requirements:
  - Rigorous code testing of active components (pumps, fans, diesels, valves)
  - Hundreds of safety-grade active components
  - High maintenance burden, frequent outage work
- Specific aging concerns:
  - Chemical and Volume Control System (CVCS) pumps require impeller replacement/trimming
  - Mechanical seal degradation for reactor coolant pump (RCP) and LOCA risk
- Monitoring strategy:
  - Periodic fatigue evaluations at fixed intervals

AP1000 Passive Design

Passive systems inspections

- General aging requirements:
  - Few active components (only valves) and elimination of safety-grade pumps, fans, diesels
  - Focus on Inspections of passive components and systems with few and improbable degradation mechanisms
  - Dramatically reduced maintenance scope
- Specific aging concerns:
  - CVCS pumps not safety-related
  - Canned-motor RCPs: zero seal LOCA risk
- Monitoring strategy:
  - Continuous fatigue monitoring via WESTEMSTM

02

Squib Valves: Redefining Safety Component Maintenance

12
Squib Valves Per Plant
3 designs

0
Failures to Date
Across Vogtle & China fleet

4
Valve Functional Group
New redundancy definition

Controlled Environment Maintenance

- Pyrotechnic actuator with shear cap design
- Maintained in controlled, dry environment
- Disassembly and inspection vs. active component rebuild
- Few and improbable degradation mechanisms

Reducing Inspection Burden

- Redefining "redundant safety train":

From: Valve pair → To: 4-valve functional group

- Limits the number of component perturbations
- NRC review underway (ML26044A119)

03 WESTEMS: Continuous Fatigue & Aging Tracking

Westinghouse Enhanced Thermal/Electrical Monitoring System

Traditional: Periodic Evaluation

- Manual cycle counting at fixed intervals
- Conservative design transient assumptions
- No real-time feedback to operations

AP1000: Continuous WESTEMS Monitoring

- Real-time severity-based transient characterization
- Automated CUF with environmental correction (EAF)
- Feedback loop to operations for abnormal transients

WESTEMS Key Capabilities

Fatigue Usage Factor Monitoring: Continuous CUF calculation with environmentally assisted fatigue (EAF) correction per GALL X.M1

Severity-Based Transient Mgmt: Optimizes licensing basis margins; actual transient severity vs. conservative design assumptions

Diagnostic Trending: Projection of transient counting and fatigue usage results enables proactive plant management

NRC-Approved Methodology: WCAP-17577 Rev. 2 accepted for ASME Section III NB-3200/NB-3600 piping and component design (AP1000 Class 1)

04 Thermal Transient Tracking: The Next Priority

Without active systems, tracking thermal transients becomes the most critical aging management activity

1 Monitor

WESTEMS captures real-time temperature, pressure, and flow data from existing plant sensors

2 Characterize

Severity-based classification assigns each transient to design basis categories automatically

3 Evaluate

Cumulative usage factor computed with environmental correction; compared against code limits

4 Optimize

Actual response data enables reclassification of events to less severe categories with more available cycles

Key Insight: Severity-based approach optimizes licensing basis margins, enabling plants to operate longer without re-evaluating licensing basis transients. Deployed at 18+ nuclear units in the US and Europe.

05 Real-World Passive Safety System Actuations

Events at both China and U.S. AP1000 units have actuated passive safety systems, providing critical aging data

Vogtle Unit 3 — PRHR Actuations

- Two complicated scrams with PRHR and safeguards actuation (Q3 2024)
- Root cause: Overly conservative PRHR actuation logic design
- Resulted in unnecessary PRHR actuations, safeguards actuations, and excessive plant cooldowns
- NRC 95001 supplemental inspection completed March 2025
- Corrective actions implemented; Unit 3 returned to Column 1
- Design modifications to actuation logic underway

NRC: ML25099A013, ML24305A249

Aging Management Implications

- China AP1000 units have also experienced passive system actuations during operations since 2018
- Each actuation event provides actual thermal transient data for fatigue analysis
- Actual plant response often less severe than conservative design assumptions
- Opportunity to reclassify events to transient categories with more available cycles
- Reduces cumulative fatigue usage factor impact
- Builds real-world dataset for probabilistic life modeling

06 Fatigue Usage Optimization from Event Analysis

Design Transient Assumption

Conservative bounding cycle definitions per ASME Section III

→

Actual Event Response Data

WESTEMS captures real thermal/pressure response during event

→

Transient Reclassification

Event severity compared to design basis; may qualify as milder transient

→

Extended Component Life

More available cycles in the reclassified transient category

Vogtle Example

The Problem: PRHR actuations in Q3 2024 created thermal transients consuming fatigue cycles at conservatively-assumed rates

The Opportunity: WESTEMS data from actual events shows actual thermal response was less severe than the bounding design transient

The Benefit: Based on actual response, events can potentially be classified as transients with more available cycles, extending component qualified life

07 The Future: From Monitoring to Prediction

NOW

Continuous Monitoring

WESTEMS provides the foundation: real-time fatigue tracking, severity-based transient management, and automated surveillance. This is where AP1000 plants operate today.

NEAR-TERM

AI / Predictive Maintenance

Machine learning models trained on fleet-wide operational data detect degradation signatures weeks before failure. Component health scoring replaces time-based inspections.

FUTURE

Probabilistic Remaining Life

Digital twin-integrated probabilistic models compute remaining useful life distributions. Plant-specific, condition-based life extension decisions with quantified uncertainty.

Connecting Nuclear: *This data-driven optimization framework connects today's operating experience to the future — enabling extended plant life, informing next-generation reactor designs, and building a shared knowledge base across the growing global nuclear fleet.*

Key Takeaways

1. AP1000 replaces rigorous ASME testing of active components with inspections of passive components in controlled environments — fundamentally fewer and less probable degradation mechanisms

2. Squib valves: zero failures across Vogtle and China fleet. Redefining redundancy from valve pairs to 4-valve functional groups further reduces unnecessary component perturbations

3. WESTEMS enables continuous fatigue and aging tracking, replacing periodic evaluation with real-time severity-based transient characterization and CUF monitoring

4. Real passive system actuations at Vogtle and China provide actual thermal response data — enabling reclassification of events to less severe transient categories

5. Continuous monitoring is the foundation for the next leap: AI-driven predictive maintenance and probabilistic remaining life modeling across the growing AP1000 fleet

Questions & Discussion