A SYSTEMATIC APPROACH TO IMPLEMENTING AGING MANAGEMENT AT NUCLEAR WASTE FACILITIES

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ABSTRACT

Many of nuclear waste facilities were built, retrofitted, or refurbished in the late 1970s and 1980s at the time of awaking environmental consciousness and Federal regulations. The operational readiness and safety of an aging nuclear waste facility need to be addressed and managed now. A systematic process needs to be defined and executed by the U.S. Department of Energy with industry's inputs. Lessons can be learned from life extension of transportation infrastructure, renewal of nuclear reactor operations, environmental management's risk management process, Nuclear Regulatory Commission's risk informed process, and safety analysis/safety evaluation process. This article identifies the needs, proposes a systematic process, and gives a few examples of aging management applicable to nuclear waste facility. Time is now to be effective in executing aging management programs appropriately, effectively, and pro-actively.

BACKGROUND

Many nuclear waste facilities were built, retrofitted, or refurbished in the late 1970s and 1980s at a time of awakening environmental consciousness and Federal regulations. After 30-40 years of operations, authors discuss the continuing operational readiness and aging management needs of nuclear waste facilities to be addressed and managed now. A systematic process needs to be defined and executed by the U.S. Department of Energy (DOE) with industry's input. The nuclear waste facilities aimed at in this article for discussion include legacy waste storage tanks containing high radioactivity waste, nuclear waste treatment facilities, waste characterization facilities, waste transferring activities, and non-passive waste storage or disposal facilities. Components and systems of particular interest include containment, structures, valves, pumps, piping, cables, sensors, monitoring and characterization instruments, control instrumentation, electrical systems, fire protection, ventilation, and other safety features.

Prior to the mid 1990, decommissioning was considered the primary alternative when a nuclear power plant reached its term of license. The Nuclear Regulatory Commission (NRC) published its license renewal rule, Title 10 of the Code of Federal Regulations (10 CFR) Part 54, on May 8, 1995, providing the requirements for renewal of operating licenses for nuclear power plants [1]. The 10 CFR 54.21(a)(1)(i) requires a management review of aging containment structures and other systems or components to ensure that the effects of aging will be managed so their intended functions will be maintained for the period of extended operation. In 1990, the Nuclear Management and Resources Council (NUMARC), now the Nuclear Energy Institute (NEI), submitted for NRC review the industry reports (IRs), NUMARC Report 90-01 and NUMARC Report 90-10, addressing aging management issues associated with pressurized water reactor (PWR) and boiler water reactor (BWR) containments for license renewal. The nuclear industries and the NRC worked together to develop a regulatory framework for license renewal process [1] and life extension of nuclear power reactor; the operational life can now be extended from 40 to 60 years or longer with confidence.

Attention should be paid to addressing the aging management of nuclear waste facilities. An approach to aging management for nuclear waste facility can gain benefits from a mature system applied in licensing renewal process for nuclear reactors. Lessons can also be learned from efforts such as life extension of the transportation infrastructure, renewal of nuclear reactor operations, Environmental Management's (EM) risk management process, NRC's risk informed process, and the safety analysis/safety evaluation process. This paper identifies the needs, proposes a systematic process to address the needs, and offers a few examples of how the application of an "aging management" approach is applied to nuclear waste facilities.

AGING EFFECTS

The determination of applicable aging effects is based on degradation that has occurred and those that potentially could cause structure and component degradation. The materials, environment, stresses, service conditions, operating experience, and other relevant information need to be considered in identifying applicable aging effects. The effects of aging on the intended function(s) of structures and components also should be considered.

For a nuclear power plant, relevant aging information usually can be found in the following documents:

- plant-specific maintenance and inspection records
- plant-specific site deviation or issue reports
- plant-specific NRC and Institute of Nuclear Power Operations (INPO) inspection reports
- plant-specific licensee self-assessment reports
- plant-specific and other licensee event reports (LERs)
- NRC, INPO, and vendor generic communications
- GSIs/unresolved safety issues (USIs)
- U.S. Nuclear Regulatory Guide (NUREG) commission reports
- Electric Power Research Institute (EPRI) reports

The applicable aging effects could result from normal operation or from abnormal events. During normal operation, aging effects could result from plant/system operating transients and plant shutdown. Additionally, specific aging effects from abnormal events need to be considered for its contribution to the aging effects on structures and components. An example of an abnormal event causing aging effects is if a resin intrusion has occurred in the coolant system at a particular system; the contribution of this resin intrusion event to aging needs to be considered for that system. Design basis events (DBEs) are abnormal events. They could include a design basis pipe break, a loss of coolant accident (which is unlikely to occur in a waste facility), and a safe shutdown earthquake (SSE) event. Potential degradations resulting from DBEs need to be considered in an Aging Management Program. Other abnormal events should be considered on a case-by-case basis. For example, the misuse of equipment is an abnormal event.

An aging effect due to an abnormal event does not preclude aging effect from occurring during normal operation for the period of extended operation; for example, clad cracking in a pressurizer should be attributed to an abnormal dry-out of the pressurizer. Although dry-out of a pressurizer is an abnormal event, the potential for clad cracking in the pressurizer during normal operation should be evaluated for license renewal. This is because the pressurizer is subject to extensive thermal fluctuations and water level changes during plant operation, which may result in clad cracking given sufficient operating time. The abnormal dry-out of the pressurizer at that certain plant may have merely accelerated the rate of the aging effect.

Frequently, nuclear waste facilities are exposed to environmental conditions without engineered protection or added containment. Humidity, arid conditions, or extreme cycles of hot and cold conditions should be considered.

AGING MANAGEMENT PROGRAM

"Aging management" is defined as a systems-based approach that addresses both the hard assets associated with an aging facility (e.g., engineered systems, structures and components) as well as soft assets (e.g., workforce needs/constraints, knowledge creation/capture and transfer, public outreach and involvement). The aging management program is not intended to demonstrate absolute assurance that structures and components will not fail, but rather that there is reasonable assurance that they will perform such that the intended functions are maintained consistent with the current safety basis during the period of extended operation.

Aging management at nuclear waste facility provides a different perspective from safety basis. In addition to addressing the aging effect of SCs, SSCs, or inventory release, the proposed aging management program addresses the aging effect on hazards and operational sustainability. As an example of aging effect on hazards, it is evident the compositions of organics and radionuclides change after 20 years in the HLW tank farms. An effective aging management program could reduce the flammable gas hazard in the tank farms. Subsequently, the safety controls at tank farms could be relaxed to adequately control the associate hazard.

The aging effects also apply to nuclear waste hazards for management. For example, flammable gas is one of the major safety issues at the Hanford nuclear waste site and requires extensive resources to address and resolve the issue. The source of these flammable gases, mainly hydrogen, is the soluble organics in the waste. The degradation of organics complexant through thermolysis and radiolysis will generate hydrogen. Water under radiation will also generate hydrogen. However, over time, the radionuclide inventory is reduced due to decay, the waste temperature is decreased due to smaller radionuclide inventory, and the organic concentration is also decreased due to continued degradation, etc. All these factors are aging effects that contribute to the decrease of the hydrogen generation rate. By continued monitoring and evaluating of these hazards, management will notice the decrease in the size of hazards such that the resources used in the flammable gas issue can be re-allocated.

There are generally four types of aging management programs (AMPs): prevention, mitigation, condition monitoring, and performance monitoring. *Prevention program*s preclude the effects of aging. For example, coating programs prevent external corrosion of a tank. *Mitigation programs* attempt to slow the effects of aging. For example, water chemistry programs mitigate internal corrosion of piping. *Condition monitoring programs* inspect for the presence and extent of aging effects. Examples are the visual examination of concrete structures for cracking and the ultrasonic examination of pipe wall for erosion-corrosion induced wall thinning. *Performance monitoring programs* test the ability of a structure or component to perform its intended function(s). For example, the ability of the tubes of heat balances on heat exchangers to transfer heat is tested. More than one type of AMP may be implemented to ensure that aging effects are managed. For example, in managing internal corrosion of piping, a mitigation program (water chemistry) may be used to minimize susceptibility to corrosion. However, it may also be necessary to have a condition-monitoring program (ultrasonic inspection) to verify that corrosion is indeed insignificant.

An acceptable AMP usually consists of the 10 elements as described in Table 1.

Table 1. Elements of an Aging Management.

Element	Description
1. Scope of program	Scope of program includes the specific facilities, structures, systems, and components subject to an AMR for license renewal.

Element	Description
2. Preventive actions	Preventive actions prevent or mitigate aging degradation.
3. Parameters monitored or inspected	Parameters monitored or inspected should be linked to the degradation of the particular structure's or component's intended function(s).
4. Detection of aging effects	Detection of aging effects occurs before there is a loss of structure or component intended function(s). This includes aspects such as method or technique (i.e., visual, volumetric, surface inspection), frequency, sample size, data collection, or timing of new/one-time inspections to ensure timely detection of aging effects.
5. Monitoring and trending	Monitoring and trending provide predictability of the extent of degradation and timely corrective or mitigating actions.
6. Acceptance criteria	Acceptance criteria, against which the need for corrective action will be evaluated, ensure that the structure or component intended function(s) are maintained under all design conditions during the period of extended operation.
7. Corrective actions	Corrective actions, including root cause determination and prevention of recurrence, should be timely.
8. Confirmation process	Confirmation processes ensures that preventive actions are adequate and that appropriate corrective actions have been completed and are effective.
9. Administrative controls	Administrative controls provide a formal review and approval process.
10. Operating experience	Operating experience of the AMP, including past corrective actions resulting in program enhancements or additional programs, provides objective evidence to support the conclusion that the effects of aging will be managed adequately so that the structure and component intended function(s) will be maintained during the period of extended operation.

A SYSTEMATIC APPROACH TO AGING MANAGEMENT

The needs and process associated with a systematic aging management approach include:

Establishing Standards and a Regulatory Framework

With the initiatives from the DOE Secretary's Office on regulatory reform, a clear standard should be established. Lessons can be learned from efforts such as life extension of the transportation infrastructure, renewal of nuclear reactor operations, EM's risk management process, NRC's risk informed process, and the safety analysis/safety evaluation process.

Reviewing and assessing generic aging lessons learned in DOE's nuclear waste facility to identify generic aging management concerns

An Expert Panel Review can be used to identify important information needs for facility operators. Each type (or category or generic design) of a critical facility (such as vitrification, grouting, HLW tanks, characterization laboratory, NDA characterization, dry SNF storage, wet SNL storage, LLW storage, LLW disposal, etc.) would be reviewed to determine if it meets the existing or newly established technical and regulatory requirements [2]. Specifically, the facility steward should identify those systems, structures, and components that are within the scope and subject to an aging management review and must also identify applicable aging mechanisms and describe programs in place to manage aging. A facility operator should be required to demonstrate that the effects of aging on structures and components are managed adequately to ensure that their intended functions are maintained consistent with the current safety basis of the facility for the industrial designated life expectancy. In the "aging management" processes that affect quality of safety-related structures, systems, and components must be examined. The quality assurance (QA) requirements and program, with emphasis on corrective actions, confirmation process, and administrative controls, ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective.

Performing a Documented Risk and Safety Evaluation

A document risk and safety evaluation of each specific facility should includes site inspections to assess whether the facility operator has implemented and complied with the regulations for license renewal and verifying whether the effects of aging is managed such that the waste facility can be operated during the period of extended operation without undue risk to the health and safety of the public. The inspection teams are composed of technical, program, testing, and operational specialists. The evaluation results in a publicly available safety evaluation report.

Monitoring the performance of aging management concerns using in-service inspection and testing

In-service inspection and testing are to supplement the role of Technical Experts. It is important to perform in-service testing and characterization of fatigue, structural deterioration, and/or other early warning signs of aging. Recently, NRC amended 10 CFR 50.55a to promulgate requirements for in-service inspection of containment structures.

Other examples of monitoring could include monitoring of cracking due to cyclic loading that could occur in stainless steel, heat exchanger components exposed to treated borated cooling water greater than 60°C (>140°F) in the chemical and volume control system. Another example of monitoring is the presence of salt deposits. Reduced insulation resistance can result from the presence of any salt deposits and surface contamination and loss of material due to mechanical wear. Another example is the monitoring of absorber materials in a spent fuel pool by periodically measuring the physical and chemical properties of coupon samples that receive a higher radiation dose than the functional boral panels. Thermolysis and radiolysis in a HLW tank or process piping can further deteriorate coating of steels.

Establishing a baseline of aging management, such as replacement, renovation, housekeeping and preventive maintenance

Review of the facility's Probabilistic Risk Analysis (PRA) Summary can assist in determining individual plant examination for severe accident vulnerabilities. While the regulatory rule usually is "deterministic," probabilistic methods may be most useful, on a plant-specific basis, in helping to assess the relative importance of structures and components that are subject to an aging management review by helping to draw attention to specific vulnerabilities. The final safety analysis report/safety evaluation report documents the closure of confirmatory items addressing fatigue of Class 1 components. The facility operator should formally evaluate Architect, Engineering, and Design of Mitigation against engineering drawings to meet the updated building codes, with emerging technology deployment, and consider the changing environmental conditions. Typical structures to consider include:

- The primary containment structure or concrete integrity of a pool or shielding
- Building structures (such as the intake structure, diesel generator building, auxiliary building, and cooling tower, rail, or shipping infrastructure)

- Component supports (such as cable trays, pipe hangers, elastomer vibration isolators, equipment frames and stanchions, and HVAC ducting supports)
- Non-safety-related structures whose failure could prevent safety-related structures, systems, and components (SSCs) from performing their intended functions (that is, seismic Category II over I structures)

Typical structural components include the following: liner plates, walls, floors, roofs, foundations, doors, beams, columns, and frames.

Analyses of a storage facility and its containment/vessel with TRU when subjected to alpha or neutron embitterment (upper shelf energy, pressurized thermal shock screening criteria, and pressure-temperature limits) should be performed to demonstrate that the limiting beltline materials will satisfy the acceptance criteria for the period of extended operation. The facility steward should show that the current fatigue analysis of frame, which conservatively assumes 400 operating basis earthquakes, bounds additional years of operation. Analysis should also bind the effects of loads due to temperature fluctuations and radiation flux. A structure's monitoring program for managing aging of the structure should be considered.

Closure of Confirmatory Items

Assuring that closure of confirmatory items addressing critical components is documented in the final SAR/SER; Facility steward and the DOE should commit to performing additional actions to address aging management action items, such as fatigue of the auxiliary spray line piping and environmentally assisted fatigue of valves, pressurized line, safety injection nozzles, charging nozzles, and residual heat removal line. These commitments will ensure that the effects of fatigue are appropriately managed. Fatigue Evaluation of Metal Components for aging facility is one of the most critical items. Environmental effects on pump seals and their performance both during normal operation and during loss of seal cooling conditions are important when pumps are in a hot-cold day-night cycles for many years. Natural deterioration can affect the integrity of structure or coating of pipes, etc.

Addressing human capital and man-machine interfaces between aging workers and their interface with and within the aging facility – a need that is talked about a lot with little obvious actual action resulting

Implementing a process to maintain competence and the transfer of knowledge from aging workers to emerging workers is required with acceptance by the Labor Union, workers, and management. This includes how to maintain and document the Qualification of a "Skilled Worker," working hours, shared responsibilities, and a formal transition plan.

A critical issue of "Aging Management" will be shortages of nuclear engineers, health physicists, radiochemists, and nuclear waste specialists in our colleges, universities, and professional training institutes. Without emerging mid-level managers, engineers, or students, skills and knowledge cannot be timely transitioned. Aging Management needs to ensure proper and timely response of aging staff during abnormal conditions.

Addressing public and worker participation and acceptance as enablers of the extension/life of a nuclear waste facility

The eight elements above provide the framework for a systems-based approach to managing aging nuclear waste facilities. Now is the time to execute effectively this systems-based approach--appropriately, effectively, and pro-actively [3].

REFERENCE:

1. NUREG-1800, Rev 1, Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, 2005
2. NUREG-1801, Rev 1, Generic Aging Lessons Learned (GALL) Report, 2005
3. NEI 95-10, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule," Nuclear Energy Institute, June 2005 (Revision 6).