AGING MANAGEMENT FOR STRUCTURAL MATERIALS USING THE COMMODITIES APPROACH

Farook Y. Chandiwala, PE, Senior Engineer, Southern Company Generation and Energy Marketing

William P. Evans, PE, Senior Engineer, Southern Company Generation and Energy Marketing

ABSTRACT

Southern Nuclear Operating Company, on behalf of itself and the plant owners, has applied for renewal of the operating licenses for the Edwin I. Hatch Nuclear Power Plant Units 1 and 2, located near Baxley, Georgia. The United States Nuclear Regulatory Commission is in the process of reviewing that application. The management of the aging of passive structures and components is of primary importance to the consideration of renewal of a nuclear power plant's license to operate. As a follow-up to a previous paper presented at the 7th International Symposium on "Current Issues related to Nuclear Power Plant Structures, Equipment and Piping", this paper will describe the aging management review process for structures within the scope of the 10CFR54. This paper will describe the process that Southern Nuclear Operating Company used to identify the structural materials of concern, beginning with structures known to be in-scope for license renewal. The paper will focus on the process of determining the materials, the environments to which the materials are exposed, the plausible and detrimental aging effects, and the aging management programs for those aging effects. Through the discussions in the paper, the commodity approach will be described and its advantages highlighted. Several examples of structures within the scope of the license renewal rule will be used within the paper to show how the aging management review process worked for Plant Hatch, and to show how these reviews were presented in the Plant Hatch License Renewal Application.

INTRODUCTION

The governing regulation for license renewal is Title 10 of the Code of Federal Regulations Part 54 (10CFR54)[1]. This regulation requires an applicant to perform and submit an integrated plant assessment (IPA) for each plant for which a renewed license is desired. The IPA demonstrates that the applicant has identified the nuclear power plant facility's structures and components that require an aging management review in accordance with 10CFR54.21(a). The IPA also demonstrates that the effects of aging of the functionality of such structures and components will be managed to maintain the current licensing basis (CLB) of the facility "such that there is an acceptable level of safety during the period of extended operation."

To prepare the IPA for Plant Hatch, Southern Nuclear reviewed the structures and components of the power plant in a scoping and screening process, described in part in a previous paper on this subject. The Plant Hatch License Renewal Application (LRA) [2] describes the process in detail. This paper addresses portions of the screening process and the process Southern Nuclear used to identify the materials, environments, aging effects, and aging management programs to ensure that aging of structures within the scope of the Rule will be maintained such that an acceptable level of safety exists during the period of extended operation.

STRUCTURES EVALUATED

Plant Hatch is a dual unit nuclear power plant consisting of two boiling water reactors rated at 911 and 917 MWe. The structures that are within the scope of the license renewal rule include:

- Reactor Buildings (including Containment Structures and Spent Fuel Pools)
- Control Buildings
- Diesel Generator Building
- Main Stack
- Intake Structure
- Portions of the Turbine Building, and
- Several Yard Structures

For the purposes of this paper, the intake structure, the containment structure and the spent fuel storage pool will be discussed. Elements of the discussion can readily be applied to the other structures.

MATERIALS EVALUATED

Structural materials are grouped together and are evaluated for the environments to which they are exposed. The materials evaluated are based on similarities of construction, and include, but are not limited to, concrete, carbon steel, stainless steel, aluminum, sealants and seal materials (made from polymers) and acrylic (used in tornado relief vents). These materials are used in one or more of the structures listed above. The sources for the materials determination included the Hatch FSAR, project drawings, vendor documents, Technical Specifications, and System Evaluation Documents.

ENVIRONMENT DETERMINATION

The structures listed above are exposed to varying environmental parameters, such as humidity, elevated temperatures, radiation, etc. The response of the materials listed above varies according to their exposure to these different environments, either singly or in combination. When some of these environments are significantly deleterious and are sustained for sufficient periods of time, age-related material degradation can result.

Though the materials are located in different structures, the material environment leads to similarity in material degradation. This similarity of degradation helps to group the materials into "commodities", as will be shown below.

COMMODITY GROUP FORMATION

Items that have similar materials of construction and are exposed to similar environments can be grouped into "commodities". All items in a given commodity group that are both passive and long-lived are addressed by a common evaluation documented in Aging Management Review (AMR) Reports. Passive components do not change position or state in the performance of their intended safety functions. Long-lived components are not subject to replacement based on a qualified life or specified time period.

Accordingly, for the structures considered in this paper, Southern Nuclear formed commodity groups and prepared corresponding AMR reports to address the plausible degradation mechanisms. The AMR reports include an evaluation of the management programs and methods for detrimental mechanisms. The commodity groups are concrete, structural steel, structural steel for primary containment, stainless steel (for spent fuel pool and refueling canal), aluminum, fire doors, component supports, sealants, and acrylic.

The AMR reports further evaluated these materials by their environments, e.g. carbon steel in air, carbon steel submerged, buried carbon steel, stainless steel in air and demineralized water, aluminum in air and demineralized water, etc.

The advantages of the "commodities" approach is that one can address, in one document, all aging effects for the same material subject to similar environment, regardless of structure or system. For example, the results of the evaluation for the Spent Fuel Pool stainless steel liner plate, subject to a fluid environment, can be used for a similar stainless steel liner plate located elsewhere in an environment of a fluid of similar chemistry. This way, repetitious evaluations can be minimized or totally eliminated, saving time and effort. Further, the use of one document assures consistent application of the conclusions throughout all areas of the application. An additional advantage to the “commodities” approach is that structural components are not usually uniquely identified in plant documentation, and a discrete list of all of the components would be cumbersome to include in an IPA.

AGING MECHANISM/EFFECT DETERMINATION

An age-related degradation mechanism is considered significant, if, when allowed to continue without any additional prevention or mitigation measure, it cannot be shown that the component would maintain its safety function during the license renewal period. The set of age-related degradations shown in this paper was derived from two EPRI documents titled, "Class I Structures License Renewal Industry Report," and "BWR Containments License Renewal Industry Report" and from, "Aging Effects for Structures and Structural Components," prepared for the B&W Owners Group [3] [4] [5]. These industry documents indicate that the results were obtained from a review/evaluation of component service experience, relevant laboratory data, and related experience from other industries. Furthermore, Southern Nuclear used the operating experience at Plant Hatch in the AMR process to evaluate whether an aging effect required management in the renewal term.

Similar aging effects can result from different mechanisms. The technical evaluation of a particular age-related degradation mechanism and its effects on the continued safety performance of a particular in-scope structural component leads to one of two conclusions:

1) the effects of the mechanism are potentially significant to that component, and further evaluation is required relative to the capability of effective programs to manage the effects of the age-related degradation, or
2) the effects of the age-related degradation are not significant to the ability of that component to perform its intended safety function throughout the license renewal term.

For the latter case, Southern Nuclear provided specific criteria and corresponding justification in the AMR reports such that the reports could be used generically to resolve age-related degradation issues for other structural components.

SPECIFIC AGING EFFECTS AND AGING MANAGEMENT BY COMMODITY

An aging effect may be defined as a change in a system, structure, or component's performance, or change in physical or chemical properties resulting in whole or part from one or more aging mechanisms. An aging mechanism is any aging process that may result in one or more aging effects. Aging effects are generally used in the license renewal process rather than the mechanisms because, in many cases, programs can be established to manage aging effects without a detailed consideration of the underlying mechanism.

Examples of aging effects include loss of material, cracking, loss of fracture toughness, loss of adhesion, and change in material properties. For each commodity, a systematic assessment evaluated a set of aging effects drawn from an extensive review of literature that represents the collective experience of the U.S. nuclear power industry. The complete assessment for each environment/material combination is contained in the AMR reports. Plant Hatch-specific operating experience was examined for each commodity group, in part, to identify whether other aging effects specific to Plant Hatch should also be addressed. The results of the Hatch-specific operating experience review were incorporated into the aging effects determination.

AGING EFFECTS

The following definitions of aging effects are provided below for clarification:

Change in Material Properties – Any change in a material which is detrimental to that material's ability to meet its design requirements. Mechanisms that may result in a change in material properties include galvanic corrosion, thermal degradation, strain aging and irradiation.

Cracking – Service induced cracking of materials includes both flaw initiation and growth within concrete, concrete masonry, base metals and associated weld materials, and nonmetallics. Aging mechanisms that may result in crack initiation and growth include fatigue, intergranular attack, stress corrosion cracking, weathering, settlement, and thermal degradation.

Loss of Adhesion – This aging effect indicates a loss of the bond between a structural sealant and the surface to which it is mated. Weathering, ultraviolet radiation and the intrusion of moisture between the sealant and its mating surface cause a loss of adhesion.

Loss of Fracture Toughness – A change in the material properties of a metal such that design requirements are potentially compromised. Aging mechanisms that contribute to loss of fracture toughness include irradiation embrittlement and thermal embrittlement.

Loss of Material – A reduction in the material content of a component or structure and may occur evenly over the entire component surface or be confined to localized areas. Aging mechanisms which may result in loss of material include: corrosion of embedded steel in concrete, crevice corrosion, erosion corrosion, galvanic corrosion, general corrosion, selective leaching, microbiologically influenced corrosion, pitting, thermal degradation, and wear.

AGING MANAGEMENT REVIEWS

Some abbreviated examples of AMRs for concrete, aluminum, steel, and stainless steel follow. Due to limitations of space, this paper will only evaluate one material, concrete, in detail.

Aging Management Review for the "Concrete" Commodity

This commodity group includes concrete components (i.e. walls, beams, slabs, columns, floors, roof, underground duct runs and pull boxes, foundations including those for equipment) and masonry block walls. There are no masonry block walls in the containment, the intake structure and the spent fuel pool. The concrete considered was the concrete in foundations and exterior concrete below grade, exterior concrete above grade, interior concrete slabs and walls, and unreinforced concrete (interior and above grade). The environments considered include elevated temperatures, radiation (as in the Containment), high humidity (as in the Intake Structure), buried (as in foundations), and submerged (as in the Intake Structure). The aging mechanisms evaluated for concrete were freeze-thaw, corrosion of reinforcing and embedded steel, erosion, abrasion and cavitation, creep, shrinkage, leaching of calcium hydroxide, aggressive chemicals, reactions with aggregates, fatigue, elevated temperature, irradiation, and settlement. For the masonry block walls, additional aging mechanisms evaluated include expansion and contraction and improper isolation at the joint between the masonry block walls and the supporting structural components (e.g. floor slabs or beams).

Aging Effects Requiring Management

The following are the aging effects that were determined in the concrete commodity that require aging management:

- *Loss of Material* - Cracking and Spalling due to corrosion of embedded steel at the concrete surface.

Aging Management Programs
Aging management programs determined to manage aging effects requiring management are as follows:
Protective Coatings Program
Structural Monitoring Program

Demonstration of Aging Management
What follows is a demonstration that the aging effects requiring management identified will be adequately managed during the period of extended operation.

Management of Loss of Material, Cracking, and Spalling due to Corrosion of Embedded Steel.
The *Structural Monitoring Program* (SMP) inspection process assesses the ongoing overall conditions of the listed structures, and identifies any ongoing degradation. The SMP will inspect the concrete commodities for loss of material, cracking, and spalling. The *Protective Coatings Program* provides for the prevention and mitigation for corrosion of embedded steel at the surface of the concrete.

Review of Operating Experience
A review of the Hatch-specific condition reporting database indicated that no age-related deficiencies or failures of the in-scope components were found.

Similarly, for steel, stainless steel, and aluminum, the aging management review can be summarized as follows:

Aging Management Review for the "Steel" Commodity

This commodity comprises of carbon steel and stainless steel commodities used in embed plates, anchors and bolts, component supports, fire doors, penetrations, torus shell, and drywell shell. The component supports include those for piping systems, cable trays and conduits, equipment and panels and racks. The environments considered include elevated temperatures, radiation (as in the Containment), and high humidity (as in the Intake Structure). The aging mechanisms evaluated were general and local corrosion (crevice, pitting, galvanic, stress corrosion cracking (SCC), and MIC), wear, fatigue, strain aging, differential settlement, elevated temperature, irradiation, and self-loosening of bolts.

Aging Effects Requiring Management
The aging effects and mechanisms that were determined to require aging management were:

- Loss of material due to general corrosion, crevice corrosion, pitting, and microbiologically influenced corrosion (MIC), of carbon steel and of submerged stainless steel components, and
- Cracking due to fatigue of the torus.

Aging Management Review for the "Stainless Steel" Commodity

This commodity comprises of stainless steel commodities used in the spent fuel pool and the refueling canal in the form of liners, spent fuel storage racks, leak chase system, anchors and bolts. Several aging mechanisms were studied, namely, crevice and pitting corrosion, microbiologically influenced corrosion (MIC), general surface corrosion, intergranular attack (IGA), SCC, elevated temperature and irradiation for the stainless steel in air and in a demineralized water environment.

Aging Effects Requiring Management
The aging effects and mechanisms that were determined to require aging management were:

- Loss of material due to crevice and pitting corrosion and MIC in the demineralized water environment.

Aging Management Review for the "Aluminum" Commodity

The aluminum commodity comprises of the seismic restraint for the spent fuel storage racks, the new fuel storage racks, the tornado vent assemblies, and conduit, raceway and cable tray components. It also includes other miscellaneous items, such as blowout panels, control rod drive handling platform and countersunk head rivets in the fuel/control rod handling equipment. The mechanisms evaluated included general corrosion, local corrosion (galvanic attack, crevice corrosion, pitting, erosion-corrosion and flow-accelerated corrosion, MIC, and selective leaching), SCC, IGA, elevated temperature, and irradiation.

Aging Effects Requiring Management
The aging mechanisms for aluminum that were determined to require aging management were:

- Loss of material due to galvanic attack, crevice corrosion, pitting, and MIC in the demineralized water environment.

AGING MANAGEMENT PROGRAMS

Once the aging effects that require management for the several commodities are determined, the applicant must make a demonstration "that the effects of aging on the functionality of such structures and components will be managed to maintain the CLB such that there is an acceptable level of safety during the period of extended operation." (10CFR54.4). The NRC Generic Aging Lessons Learned (GALL) report provides guidance on the nature of the demonstration. From the GALL report [6], an effective demonstration will have ten attributes to describe the program:

1. The program description will define the scope of the program detailing to which SSCs the program applies and for which aging effects the program is effective in management.
2. The program description will state the preventive actions within the program that mitigate or prevent the applicable aging effects.
3. The program description will state the parameters that the program monitors monitored or for which the program inspects (parameters monitored or inspected should be linked to the effects of aging on the particular structure and component intended functions).
4. The program description will contain a discussion of whether the program detects aging effects and the method whereby the program detects the aging effects (detection of aging effects should occur before there is a loss of any structure and component intended function).
5. The program description will state the kinds of monitoring and trending the program uses. This monitoring and trending should provide for prediction of the extent of the effects of aging and timely corrective or mitigative actions. The monitoring, inspection, testing frequency, and sample size should be appropriate for timely detection of aging effects.
6. The program description will state the acceptance criteria for monitoring, trending, and inspection elements of the program. These acceptance criteria, against which the need for corrective action will be evaluated, should ensure that the particular structure and component intended functions are maintained under all CLB design conditions during the period of extended operation.
7. The program description will state the kinds of corrective actions that are allotted for the program. The corrective actions, including root cause determination and prevention of recurrence, should be timely.
8. The program description will discuss the confirmation process, which should ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective.
9. The program description will describe the administrative controls contain within the program. The administrative controls should provide a formal review and approval process.
10. The program description will describe the operating experience involving the aging management program, including past corrective actions resulting in program enhancements or additional programs. This operating experience should provide objective evidence to support a determination that the effects of aging will be adequately managed so that the structure and component intended functions will be maintained during the period of extended operation.

It is not required that individual aging management programs have all ten attributes, just those that are necessary to manage the aging effect for which the program is credited. It is also permissible to achieve aging management by combining two or more programs.

For Plant Hatch, the IPA (Appendix C of the LRA) demonstrates how the aging effects will be managed. Appendix B of the Plant Hatch LRA contains a more detailed description of the attributes of the aging management programs, although the GALL report was not applicable at the time the Hatch LRA was issued. For Plant Hatch, most often two or more programs were combined to manage an aging effect. This was due in part because the commodity groups contained components from many systems and also because the LRA treats the Corrective Actions Program as a separate and distinct program used to ensure that attributes seven, eight, nine, and ten are met in the demonstration.

It is important to note that the example aging management programs in the GALL report generally stand by themselves. However, in the main body of the GALL report, there are many effects for which the NRC has stated that the example generic programs, and existing industry programs, are not sufficient to demonstrate the effects will be managed. The GALL report details the attributes that require plant specific treatment, either through confirmatory inspections or other program elements.

To manage the effects of aging in the example structures of this paper, Plant Hatch has developed the following list of programs:

Structural Monitoring Program, Primary Containment Leakage Rate Testing Program, Plant Coatings Program, Torus Submerged Components Inspection Program, Water Chemistry Program, Suppression Pool Chemistry Control, Inservice Inspection Program, and Corrective Actions Program.

These programs apply to different components depending on the material and the environment, and are listed in the individual AMRs covering these components.

These programs either represent existing activities (e.g., the Inservice Inspection Program) or enhancements to existing activities (e.g., the structural monitoring program) with one exception. The exception is the Torus Submerged Components Inspection. This new program was created to provide a one-time inspection of submerged steel that would not have been inspected in the Plant Coatings Program or the Structural Monitoring Program. Of special interest in the new inspection are the splash zones of the torus structures as these areas may be subject to wet-dry cycling.

As an example, the details of the Structural Monitoring Program are provided below.

INTEGRATED PLANT ASSESSMENT DEMONSTRATION

The Structural Monitoring Program (SMP) covers the most structures within the scope of this paper. The Structural Monitoring Program is identified in LRA Table 3.3.1-3 [2] to manage the effect of loss of material from the concrete and carbon steel in the reinforced concrete portion of the primary containment structure. The SMP has also been credited for managing loss of material in the concrete, carbon steel, and galvanized steel structural commodities of the Intake Structure (LRA Table 3.3.1-10). The IPA requires a demonstration that aging effects will be managed. The following information has been summarized and paraphrased from the update to the Plant Hatch LRA.

Structural Monitoring Program

The Plant Hatch SMP provides a stepped, condition monitoring and appraisal process for structures and components within the scope of the Maintenance Rule (10 CFR 50.65) [7] and the License Renewal Rule (10 CFR 54). The program is patterned after the Westinghouse Owners Group Life Cycle Management/License Renewal Program [8].

Program Scope *(Scope of the program includes the specific structure, component, or commodity for the identified aging effect.)*

For purposes of this paper, the Structural Monitoring Program monitors structures, components and commodities in the Intake Structure and the Reactor Buildings (including the containment structure).

Preventive or Mitigative Actions *(Preventive actions to mitigate or prevent aging degradation.)*

The SMP is a condition-monitoring program that utilizes visual inspections to identify aging effects prior to any loss of intended function. As such, there are no preventive or mitigative attributes associated with this program.

Parameters Inspected or Monitored *(Parameters inspected or monitored are linked to the degradation of the particular intended function.)*

Concrete structures are inspected for cracking and spalling. Steel structures and components are inspected for corrosion.

Detection of Aging Effects *(The method of detection of the aging effects is described and performed in a timely manner).*

The SMP inspection process assesses the ongoing, overall conditions of the buildings and structures, and identifies any ongoing degradation. Structure condition is assessed through a visual inspection. Inspections include those items normally accessible, as well as those below ground or embedded when they are exposed during the normal course of operations and maintenance.

Structures are monitored for changes in previously identified findings and for newly developed conditions. Trending of such findings is performed to predict degrading conditions and to determine the potential long-term impact of the finding. Qualified personnel, using detailed checklists, inspection tools and preparations perform the inspections. All inspection results are documented in checklists and noted degradation may be documented utilizing digital photography.

The inspection frequency for plant structures varies according to site conditions and susceptibility to aging degradation. As a result of the baseline inspections a five-cycle inspection frequency was established for the structures monitored. This frequency will continue unless the conditions, environment, or noted degradation warrant a change. At this time, the plant has elected to inspect the intake structure every operating cycle due to humid environmental conditions. However, based on the results of future intake structure inspections, the plant may elect to go back to a five-cycle frequency. For areas of the subject buildings and structures that are inaccessible due to physical obstruction and for below grade, embedded, or buried components, inspections are performed whenever these areas are excavated, exposed, or modified.

Monitoring and Trending *(Monitoring and trending provide for timely corrective actions.)*

Initial inspections (baseline) were conducted to facilitate condition trending. Structures are monitored for changes in previously identified findings and for newly developed conditions. Trending of such findings is performed to predict degrading conditions and to determine the potential long-term impact of the finding.

The reactor building (including spent fuel areas), control building, turbine building, offgas stack, diesel building, condensate storage building, plant service water valve pits, diesel fuel storage tanks, and nitrogen storage tanks will be inspected on a 5 cycle interval. Certain areas within the reactor building will be inspected every other cycle. These include the drywell, torus (inside), and overhead cranes.

Acceptance Criteria *(Acceptance criteria are included.)*

Acceptance criteria for the inspection and criteria for categorizing the overall structure and component conditions (i.e., acceptable, acceptable with deficiency, or unacceptable) are provided in the procedure. The acceptance criteria are consistent with the recommended criteria in ACI-349.3R-1996 [9], but also include additional criteria for roof ponding, water leakage, coatings, penetration seals, etc. The results of the inspections are evaluated in accordance with the guidance given in NEI-96-03 and NRC Regulatory Guide 1.160 [10] [11]. The results of SMP inspections are forwarded to the Maintenance Rule Coordinator who determines if any condition reports should be initiated.

The NRC has required applicants to provide in their demonstration a detailed description of the acceptance criteria. The following is an example:

Concrete Components

a. Spalls less than 3/4" in depth and 8" in dimension
b. Passive cracks less than 0.040" in width, measured below any surface enhanced widening ("passive cracks" are those with no evidence of recent growth and absence of other degradation mechanisms at the crack). For cracks greater than or equal to 0.040" in width, the length of the crack will be measured / estimated and documented in the database.

Operating Experience *(Operating experience of the aging management program, including past corrective actions resulting in program enhancements or additional programs, is considered.)*

In 1996 and 1997, Plant Hatch performed an initial evaluation, as part of the Structural Monitoring Program, to establish a baseline condition of the subject buildings and structures. Southern Company visually inspected areas within the scope of the Maintenance Rule and made photographs to document notable degrees of degradation. The initial evaluations included the following structural elements: the roof, outer concrete walls and penetrations, interior concrete columns, beams, floors, walls, interior steel superstructure columns, girders and beams, foundations, anchor bolts, equipment slabs, and settlement around the building. The initial evaluation of the sealants included the outer pre-cast concrete wall panels and the CST transfer pump wall joints. Southern Company found all the inspected areas, "Acceptable - no further evaluation required." Southern Company conducted condition surveys in April 1997 and November 1997. The inspection reports concluded the same findings as previous reports. Southern Company also reviewed previous results of settlement surveys and associated calculations. All structures were found to be within acceptable settlement limits. The sealant and backing rod used to seal the joint between exterior pre-cast panels on the Unit 1 and Unit 2 reactor buildings has also been replaced to repair degraded caulking.

As can be seen, different plants may not have as many structures included in their Structural Monitoring Program, and the acceptance criteria may be different. Applicants will need to fine-tune the program demonstration for their plant. The NRC, through their description of an acceptable structural monitoring program (GALL Report. Chapter XI, Section S6), has placed restrictions on when such a monitoring program may be used in lieu of other programs. The reader is encouraged to review the GALL report for further details.

CONCLUSION

Using the commodities approach for structural components in similar environments provides an effective means to evaluate the components for aging effects that require management. The commodities approach also enables a generic treatment of structural components that might not otherwise be easily identified in an IPA.

The evaluation results can be written in a fashion that can be readily reported in the IPA for a plant's license renewal application. The results demonstrate there is a reasonable assurance that the structural components will be maintained to the extent required to support the system intended functions consistent with a plant's CLB for the period of extended operation.

REFERENCES

1. 10 CFR 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," 60FR22491, May 8, 1995.
2. Plant Hatch License Renewal Application, as updated.
3. EPRI TR-103842, Revision 1, July 1994, "Class 1 Structures License Renewal Industry Report."
4. EPRI TR-103840, Revision 1, July 1994, "BWR Containments License Renewal Industry Report."
5. BAW-2279, Aging Effects for Structures and Structural Components (B&W Structural Tools), December 1997.
6. "Generic Aging Lessons Learned Report (Draft)," USNRC: August 2000.
7. 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," 56FR31324, July 10, 1991.
8. Westinghouse Owners Group, "Life Cycle Management / License Renewal Program."

9. ACI-349.3R-1996, "Evaluation of Existing Nuclear Safety-Related Concrete Structures."
10. NEI 96-03, "Guidelines for Monitoring the Condition of Structures at Nuclear Power Plants.
11. NRC Regulatory Guide 1.160, Rev. 2, March 1997, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."