Chockie Group International, Inc.

Aging Management and Life Extension in the US Nuclear Power Industry

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Frank Gregor, P.E.
Alan Chockie

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Chockie Group International, Inc.
18532 43rd Ave. NE, Seattle, WA 98155 USA

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Executive Summary

All systems and equipment degrade over time. However, the nature and the rate of degradation depend on such factors as the design, material, construction, mode of operation, and operating environment. With effective inspection and maintenance practices aging degradation can be managed and operational life can be extended well beyond what was originally planned. For over 25 years the United States (US) nuclear power industry and the US Nuclear Regulatory Commission (USNRC) have worked together to develop aging management programs that ensure the plants can be operated safely well beyond their original design life.

This report was prepared by the Chockie Group International to provide an overview of the aging management and life extension programs and regulations within the US commercial nuclear power industry and their possible applicability to the petroleum industry in Norway. It was prepared as part of the project for the Petroleum Safety Authority (PSA) Norway entitled, *Design Life Extension Regulations* (PSA Project Reference Number: NO 99B16).

Associated with this report are two companion briefing reports that provide focused examinations of two important aspects of life extension requirements. These are *Performance Monitoring of Systems and Active Components* (CGI Report 06.21) – an examination of the Maintenance Rule requirements for effective maintenance programs, and *Condition Monitoring of Passive Structures and Components* (CGI Report 06.22) – a review of the License Renewal Rule requirements and process for aging management of passive and long-lived structures and components.

There are three important principles associated with aging management. These are:

- maintaining the structures, systems, and components (SSCs) in "as new" condition – with no reduction in performance or safety margins
- preventing failures of critical SSCs
- understanding and managing the age-related degradation mechanisms

During the operating life of a plant these aging management principles should be an integral part of the maintenance program. However, when contemplating life extension another set of issues must be considered. As the US nuclear industry and the USNRC concluded, in order to extend the operating life beyond the original design life additional economic and technical factors need to be considered.

Although the possibility of life extension for nuclear plants in the US has existed for more than 50 years, the industry and regulator have been actively developing life extension requirements for only the last 25 years. In 1954 the original licensing requirements for US nuclear power plants set a 40-year limit for operating licenses. This 40-year limit was selected based on economic considerations rather than technical limitations. However, even at that time, the Atomic Energy Act was set up to allow renewal of the operating licenses.

In the late 1970s the USNRC and the nuclear industry began to address the issues concerning life extension. The first initiatives were directed at determining whether or not the safe operation of the plant beyond its 40-year operating limit could be technically justified. That is, could the aging effects be adequately managed so the plant could be operated within the original safety margins during the period of extended operation?

To answer this question both the USNRC and the industry initiated a number of aging research programs. One of the largest aging research efforts was the Nuclear Plant Aging Research (NPAR) Program. This 10-year, multi-million dollar effort was sponsored by the USNRC and produced over 150 aging research reports. Other aging research programs by the industry complimented the work of the NPAR program. Based on the results of these programs it was concluded that many aging phenomena are readily manageable and do not pose technical issues that would preclude life extension for nuclear power plants. As long as there are effective inspection and maintenance practices the plant life is simply limited by the economic cost of repair or replacement of any components that do not meet specified acceptance criteria.

The USNRC then moved forward with the development of license renewal requirements and published the initial License Renewal Rule in 1991.

For over fifteen years the USNRC and the nuclear industry have been continuously refining both the license renewal requirements and the renewal process. There are many aspects of these efforts and lessons learned that can be of potential value to the PSA and the Norwegian petroleum industry.

The following are some of the key lessons from the development and implementation of aging management programs and life extension requirements that could be applicable to the PSA and the Norwegian petroleum industry in their consideration of life extension and aging management.

Aging Research Information

The wealth of aging related information produced by the NPAR and industry aging research programs remains a useful resource for both nuclear and non-nuclear organizations. Although the aging studies examined SSCs with respect to their operation in the nuclear plants, much of the aging degradation and aging management information is applicable to the petroleum and other industrial sectors.

Continuous Improvement

Over the years both the USNRC and the industry have been working to make the license renewal requirements and the renewal process more efficient and effective. For example, the initial version of the License Renewal Rule did not provide a predictable nor stable process – it was too open ended and too broad a scope. It was determined that many aging effects were already adequately addressed during the initial operating license period. Also, the initial Rule did not allow sufficient credit for existing programs, particularly those under the USNRC Maintenance Rule, which help manage plant aging phenomena as part of the on-going maintenance program tasks.

The resulting revised Rule established a simpler, more stable, and more predictable regulatory process. The key changes that were made included:

- focusing on the adverse effects of aging rather than identification of all aging mechanisms such that identification of individual aging mechanisms is not required
- simplifying the integrated plant assessment process and making it consistent with the revised focus on the detrimental effects of aging
- adding an evaluation of time-limited aging analyses (TLAA)
- requiring only passive, long-lived structures and components to be subject to an aging management review for license renewal, thus removing active SSCs from license renewal

Passive Versus Active

An important aspect of the US nuclear plant life extension requirements is the distinction between passive and active systems, structures, and components. Passive SSCs are those that do not move to function (such as structures, heat exchangers, cables, valve and pump bodies, and piping). Their age related degradation can only be monitored and trended by performing periodic condition assessments (such as inspections, testing, and measurements).

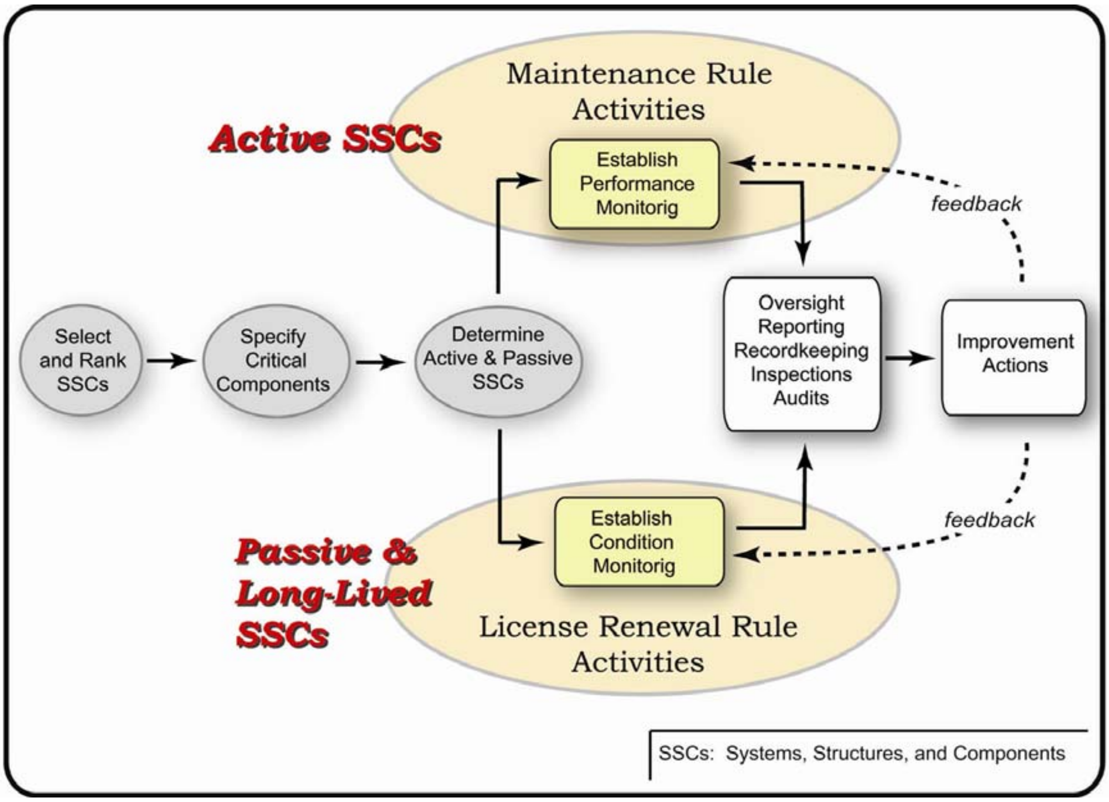
By focusing the license renewal process on safety critical passive and long-lived components the process has been reduced to manageable proportions – licensees are not required to consider all SSCs in order to justify extended operations.

A diagram of the relationship of the License Renewal and Maintenance Rules to the aging management of active and passive SSCs is shown in the figure on the next page.

During the renewal process, the licensee must confirm whether the original design assumptions will continue to be valid throughout the period of extended operation or whether aging effects will be adequately managed. The licensee must demonstrate that the effects of aging will be managed in such a way that the intended functions of passive or long-lived structures and components will be maintained during extended operation.

Need for Guidance

One of the key lessons has been the need to provide clear guidance and support to all involved parties. Both the USNRC and the industry have developed guidance documents to assist in the development of aging management programs, the preparation of the renewal application, and the review of the application. As lessons are learned these guidance documents are revised to capture new insights or address emerging issues. Along with the guidance documents, training programs and support activities have greatly reduced the time and expense in preparing, reviewing, and approving the license renewal applications.



<u>Other Aging Management Lessons Learned</u>

In reviewing the aging management and life extension efforts of the nuclear industry there are several areas where the experiences of the US nuclear power plants and USNRC could be of value to the PSA and the petroleum industry. These include:

- integrating aging management and maintenance requirements – careful management to avoid duplication of effort and non-effective maintenance tasks
- developing a long-term maintenance strategy – linking asset management to maintenance strategy with the objective to preserve the assets as long as economically feasible
- reducing component failures – being proactive to identify incipient failures, precursors, and age related degradation.
- effectiveness of condition monitoring – improving the application of diagnostic analysis to prevent failures
- establishing appropriate inspection procedures
- aging management of inaccessible equipment (since replacement and repair is not usually an economically feasible option)
- sharing experiences by tracking generic failures and monitoring effectiveness of aging management activities
- implementing pilot projects to evaluate the effectiveness of new requirements and processes

- properly quantify consequential failure costs – to support reliable conclusions and to justify implementation of a predictive maintenance and effective aging management strategy

Conclusions

The aging management and life extension process for the US nuclear industry has been refined and improved over the years. It has become an efficient and effective method to ensure that the nuclear plants in the United States can be safely operated beyond their original 40-year operating license. By dividing the safety critical systems, structures, and components into passive and active categories the industry and regulator have reduced the potentially overwhelming analysis effort to a reasonable and manageable size.

By working together, the nuclear industry and the US Nuclear Regulatory Commission (USNRC) have been able to technically justify life extension. The process has been structured to not be an economic or resource burden on either the licensees or the USNRC. However, all parties are continually reviewing the process and results to identify where improvements can be made.

The process has been selected as a viable method by many international regulatory and nuclear industry organizations, including those in Spain, Taiwan, and Korea. The International Atomic Energy Agency in Vienna has also adopted the process as the model for ensuring safe extended life operations.

The aging management and life extension process can be easily adapted to other industries. The development strategy, research material, specific elements of the process, and many of the lessons learned can all be of potential value to the PSA and Norwegian petroleum industry in ensuring safe extended operations of the facilities.

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Aging Management and Life Extension in the US Nuclear Power Industry

Background

This report on aging management and life extension actions within the United States (US) nuclear power industry was prepared by the Chockie Group International as part of the project for the Petroleum Safety Authority (PSA) Norway entitled, *Design Life Extension Regulations* (PSA Project Reference Number: NO 99B16).

Report Objective

The objective of the report is to provide an overview of the development and application of aging management and life extension programs and regulations within the US commercial nuclear power industry.

This report is a companion to two previous briefing reports that the Chockie Group International prepared for the PSA. The first, entitled, *Performance Monitoring of Systems and Active Components* (CGI Report 06.21), examined the requirements and activities associated with aging management of active systems and components. The second briefing report, *Condition Monitoring of Passive Systems, Structures, and Components* (CGI Report 06.22), addressed the programs and regulations for aging management of passive systems, structures and components for extended operation.

Information from these two briefing reports has been incorporated into this overview report.

The Principles of Effective Aging Management

It is a well-established fact that mechanical and electrical equipment can be maintained over long periods of time, using refurbishment, partial/complete replacement and reconditioning. There are some automobiles from the early 1900's that now look better and work better than when they were made. The technology to maintain equipment in an "*as new*" condition is called effective aging management. There are three basic principles that form the foundation of aging management programs.

The first principal is that there can be not reduction in the safety margins over the useful life of the plant. With respect to commercial nuclear power plants, the Nuclear Regulatory Commission (USNRC) does not permit reduction in safety margins. This implies that the plant licensees must maintain the plants in as new condition.

The second major principal is to avoid failures. The reliability of the plant will never be better than its worst performing system or component. To avoid failures, one must have the skills, knowledge, and experience to recognize pending failures and take timely corrective actions for all structures, systems, and components that are critical to the safe operation of the plant.

The third principal is to understand the behavior of materials when exposed to certain stressors (in other words, to understand the applicable aging mechanisms). This knowledge helps focuses attention on the "right places and at the right time". This also provides the information necessary for addressing the aging degradation situation with the right tools and developing effective actions to mitigate or prevent the problem from affecting safe plant operations.

Since the beginning of nuclear power in the US the industry and regulator have embraced these principles and have worked to ensure that the plants are properly maintained and operated over their operating life.

The Push for Life Extension

The operating life of the US plants has been limited to 40-years as is discussed in more detail in the following section. However, almost twenty-five years ago both the industry and the USNRC began to address the possibility of life extension. The first question they need to answer was whether it was technically justifiable and economically feasible to operate the plant beyond the original 40-year limit? If so, then what should the life extension approval process? The results of hundreds of aging research studies and many years of work have convinced all parties that life extension is both economically and technically viable. To ensure that the plants continue to operate within their design safety margins during extended operation, the USNRC in coordination with the nuclear industry had developed an effective and efficient license renewal process. The License Renewal Rule is discussed in detail in the CGI Report 06:22 and is summarized in later sections of this report.

Report Content

The first section of the report provides a brief historical perspective of the rationale for the life extension requirements and how the process has been split along the lines of active and passive systems, structures, and components.

The second section examines the key organizations that have been instrumental in the development of aging management programs. Included is an overview of how the various programs relate and complement each other.

The third section provides a discussion of the principal aging management and life extension program. The following sections examine the two key aging management requirements, the USNRC License Renewal Rule and Maintenance Rule.

The importance of industry developed aging management programs and the support and sponsorship of aging research by both the USNRC and industry is reviewed next. In the following sections a number of relevant issues and activities including early license renewal and international applications are examined.

The last part of the report discusses the lessons that have been learned over the twenty plus years in developing and implementing the aging management and life extension programs and requirements. Also as part of this later section is a summary of information, tools, strategies, and lessons that may be applicable to the PSA and Norwegian petroleum industry – how the PSA and the industry can take advantage of the extensive work and lessons to develop “focused” life extension requirements to ensure that adequate levels of safety are maintained during extended operation.

Historical Perspective

The 40-Year Operating License

When the original licensing requirements for United States commercial nuclear power plants were developed it was agreed to limit the licenses for a 40-year operating period. The 40-year limit was selected based on economic considerations rather than technical limitations.

The 40-year limit was specified by the US Congress in the Atomic Energy Act of 1954. The law was modeled on the Communications Act of 1934. This Act set up the conditions for radio stations to be licensed and operate for several years. Then the stations would be allowed to renew their licenses as long as they continued to meet their charters. Similarly, the Atomic Energy Act allows for the renewal of operating licenses for the nuclear power plants.

Congress selected 40 years for nuclear power plant licenses based on the view that this was the time required to pay off the plant investments through the anticipated income from the electrical rate base. The 40-year license term was not based on safety, technical, or environmental factors.

As specified in the Atomic Energy Act, the plants can reapply for a new operating license after 20-years of operation. If granted, the new license covers the remaining term of the 40-year operation plus up to a 20-year extension. The regulations do not set any limit on the number of renewals that a plant can apply for.

Renewal is voluntary. The decision is primarily economical and whether the licensee believes they can continue to meet NRC requirements. By June 2006, 21 nuclear plants have received regulatory approval for 20-years of extended operation. Another nine plant applications are being reviewed.

The Importance of Passive versus Active

The US Nuclear Regulatory Commission (USNRC) and the nuclear industry have developed a strategy to ensure the extended safe operation of the plants. An important element of the US strategy is the distinction between passive and active systems, structures, and components (SSCs). As a general definition, passive SSCs are those that do not move to function (such as, structures, heat exchangers, transformers, valve and pump bodies, and piping). Their age related degradation can only be monitored and trended by performing periodic condition assessments (such as inspections, testing, and measurements). An aging evaluation is typically required to identify the degradation mechanisms and to select the effective inspections and tests.

In order to ensure that the US nuclear power plants continue to maintain adequate levels of safety during extended operation beyond their original license period the USNRC has developed two important sets of requirements. These are the:

- Maintenance Rule
- License Renewal Rule

The requirements for the aging management of "active" systems and components are addressed by the Maintenance Rule (as discussed in CGI Report 06.21). The aging management of active SSCs should be part of the plant maintenance program. Good maintenance practices should identify and correct any aging degradation issues of the active SCCs and that no special license renewal aging management requirements are necessary for extended operational approval.

The focus of the License Renewal Rule is on the management of aging degradation of safety critical "passive" and long-lived systems, structures, and components (SSCs) at the nuclear power plants (as discussed in CGI Report 06.22). Long-lived items are those that are not subject to replacement based on a qualified life or specified time period.

Copies of the Maintenance Rule and the License Renewal Rule are provided in Appendices A and B, respectively.

Benefits of Life Extension

The industry and government have assessed the potential economic and environmental impact of life extension. Extending the useful plant life by 20 years for the 104 operating US plants is the equivalent of building 52 new plants. It would be most likely that these 52 replacement power plants would be coal fired. The avoidance of harmful plant emissions (SO_x, NO_x, heavy metals, and ash) is a significant environmental accomplishment (see Figure 1). Additionally, life extension is a way of minimizing the current bottleneck for the disposal of used spent fuel. Over the years, there have been numerous delays in the development of a final national repository for spent nuclear fuel. The extension of the operating licenses will allow the plants to continue to store the material on-site until the repository becomes available.

On the economic scale, each plant represents an asset value of between $1 billion to $2 billion.

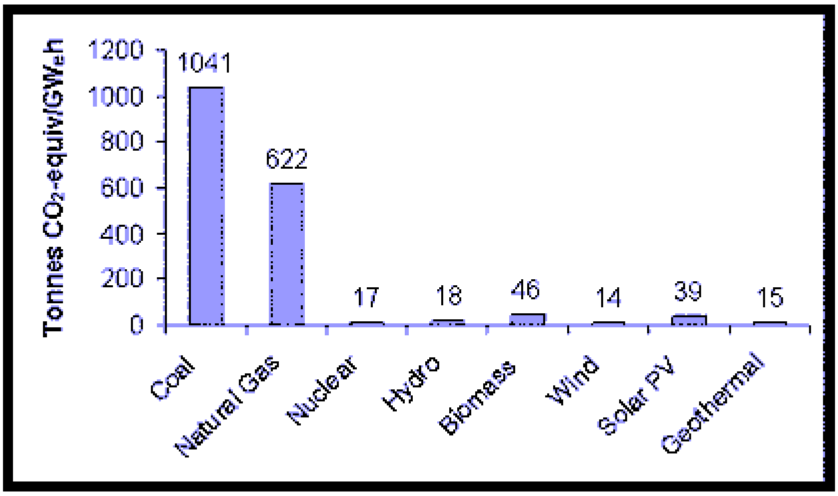

Figure 1: *Comparison of Life-Cycle Emissions*

The largest part of the operating costs comes from the depreciation of the original investment over the first 40 years and the decommissioning fees. After 40 years, the only remaining capital costs are those associated with refurbishment and replacement of aging components. The fuel and operations and maintenance costs are much lower than comparable size coal or oil fired plants. The overall benefit-to-cost ratios are on the order of 2:1 to 4:1 (a saving of between $500 and $1000 million) over the period of extended operation. According to the Nuclear Energy Institute:

> **…** *the economic value of the U.S. nuclear fleet over the remaining 40-year life of the plants is approximately $65 billion, and, over a 60-year life, assuming license renewal, is $76 billion. (Economic value is net present value of future revenue stream net of fuel and O&M costs, capital additions, etc., expressed in 2002 dollars.)*

Life extension also brought into focus the value of increasing capacity factors and the possibility of power uprate. Many plants have already completed significant power uprates, gaining 10% to 15% additional capacity with little investment. In fact, the equipment reconditioning and replacements performed as a result of life extension are made to also satisfy the needs of power uprate that is new equipment is purchased with additional capacity or upgraded. Capacity factors for the operating plants have been increasing over the last ten years, mostly by reducing the number of outage days for refueling and avoiding plant shutdowns. The average fleet capacity factor has increased about 10% to the present value of around 90%. The combined effect of power uprate and capacity factor increase has provided the equivalent electric output of about 26 additional nuclear plants. These efforts were made possible by the prospect of life extension and the attendant economic savings.

Because most of the cost of electric production from nuclear plants in the US is regulated at the state level, the net savings by the plant operators are ultimately passed on to the consumer. As a result, the economic benefits from more efficient extended operation should be realized by the utility customers.

Development of Aging Management Programs

This section examines the key organizations that have been involved in the development and improvement of programs to identify and manage the effects of aging on plant systems, structures, and components (SSCs). Also briefly discussed is the relationship among the many industry and regulatory aging management related programs.

Key Organizations Involved in Nuclear Plant Aging Management

There have been a number of industry and governmental organizations involved for over twenty-five years in the development of aging management programs and requirements for the extended operation of US nuclear plants. The key organizations are:

- Industry Organizations
    - Electric Power Research Institute (EPRI)
    - Institute of Nuclear Power Operations (INPO)
    - Nuclear Energy Institute (NEI)
    - Boiling Water Reactor Owners Group
    - Westinghouse Owners Group
    - Babcock and Wilcox Owners Group
    - Combustion Engineering Owners Group
- Governmental Organizations
    - US Department of Energy (DOE)
    - US Nuclear Regulatory Commission (USNRC)

The principal aging related activities of these various organizations are summarized below.

<u>EPRI Aging Research</u>

EPRI, the research arm of the electric utilities, sponsored life extension pilot plant and demonstration projects. These studies provided the initial technical and economic impetus for individual plant owners to look at plant life extension as a serious option for their long-term generation planning. EPRI aging research projects established the basic aging assessment technology and aging management principles. EPRI programs concerning mechanical, electrical, and structural equipment identified potential aging mechanisms and the effects of aging degradation (those that manifest themselves and can be visually or otherwise observed).

EPRI and various nuclear plant owners groups also sponsored the development of Industry Reports on Component Aging. Aging Management Tools for mechanical, electrical and structural equipment were produced to provide guidance to the plant licensees.

A similar effort was undertaken to deal with the aging management of the non-safety related portion of the plant. EPRI initiated the Preventive Maintenance Basis project to develop an industry consensus of best practices for maintenance and aging management. This project was closely followed by the EPRI Life Cycle Management program to create long-term maintenance strategies on the basis of highest reliability at the lowest costs.

INPO Maintenance Management Guidance

Initially there were no uniform implementation procedures for the aging management programs related to non-safety structures, systems, and components (SSCs). INPO lead the development of an equipment reliability guide [AP-913] that incorporating the preventive maintenance (PV) basis, life cycle management (LCM) programs, and reliability centered maintenance (RCM) programs. AP-913 has become the standard to measure plant excellence.

NEI Aging Guidelines

The Nuclear Energy Institute has been responsible for taking the lead in the development of the guidelines to assist licensees prepare the license renewal applications. The NEI-95-10 document, entitled *Industry Guidelines for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule,* provides licensees with an acceptable approach for implementing the requirements of the USNRC License Renewal Rule. This is a living document and is continuously updated based on NEI's monitoring of licensees experiences with the license renewal process. NEI continues to be the focus for interaction between the industry and the USNRC and serves as a spokesperson for the industry when new life extension or aging management issues emerge.

DOE Aging Research

The US Department of Energy (DOE) is responsible for national long-term energy planning. DOE has supported a number of the EPRI programs including those addressing mechanical, electrical, and structural equipment aging degradation. Follow-on research by DOE has included the Aging Management Guides for major components and commodities and the concrete aging research conducted by the DOE Oak Ridge National Laboratory.

USNRC License Renewal Research & Regulations

In the early 1980s the USNRC initiated a major aging research program to investigate the aging degradation of safety related equipment. This program, entitled the Nuclear Plant Aging Research (NPAR) program, examined aging degradation in both passive and active structures, systems, and components. This was a major multi-million dollar research effort lasting almost 10 years and sponsoring more than 100 aging research studies. The Program eventually generated over 150 technical reports.

The findings from the NPAR Program provided the basis for determining that extended operations of the nuclear power plants were technically justifiable. It also provided the foundation for the license renewal requirements and renewal process.

In 1991, the safety requirements for license renewal (entitled, Requirements for Renewal of Operating Licenses for Nuclear Power Plants) were adopted by the USNRC. These requirements, known as the License Renewal Rule, established the procedures, criteria, and standards governing the renewal of nuclear power plant operating licenses. These were made mandatory requirements as part of the United States Code of Federal Regulations (commonly referred to as 10 CFR Part 54).

For the next few years the USNRC in cooperation with the nuclear industry conducted a demonstration program to apply the Rule to pilot plants. The objective was to assess the effectiveness of the requirements and the application/review process. The USNRC also undertook a number of activities related to the implementation of the Rule. These included:

- developing a draft regulatory guide
- developing a draft standard review plan for license renewal
- reviewing generic industry technical aging information

Based on discussions with industry and results from the demonstration program the USNRC determined that revisions to the Rule were needed. The USNRC found that many aging effects are dealt with adequately during the initial license period. In addition, the USNRC found that the review did not allow sufficient credit for existing programs, particularly those under the USNRC Maintenance Rule, which also helps manage plant aging phenomena.

In summary, the amended Rule established a regulatory process that is simpler, more stable, and more predictable than the initial License Renewal Rule. It put the focus of the license renewal assessment on the licensees aging management activities concerning passive and long-lived SSCs. It also clarified the focus on managing the adverse effects of aging rather than identification of all aging mechanisms. The changes to the integrated plant assessment (IPA) process were to make it simpler and more consistent with the revised focus on passive, long-lived structures and components

Relationship of Aging Management Programs

The original life extension pilot plant studies performed in the 1980's did not differentiate among passive and active components or the safety and non-safety related portions of the plant. The focus of these studies was to determine the critical components and life ending scenarios as a result of progressive unmitigated degradation and from this to establish a realistic attainable plant life. When the USNRC started to develop the License Renewal Rule, they had the benefit of the pilot studies results and included the passive and active components within the scope of the Rule. This turned out to be a bad decision, as industry tried to cope with very costly implementation costs and impractical application of the requirements. Because the Maintenance Rule was being prepared by the USNRC in the same timeframe and dealing exclusively with the performance monitoring of active components and systems, the License Renewal Rule was revised to only encompass long-lived passive components and structures. Notably, the USNRC regulations only apply to the regulated safety related portions of the plants, about one-third of the total plant. (A detailed review of the Maintenance Rule is provided in CGI Report 06:21.)

When life extension or license renewal is considered, the entire plant needs to be assessed and prepared to meet its extended life goal. To this end the industry sponsored a number of equipment reliability research studies concerning the aging degradation for the non-safety portions of the plant. The initial focus was the development of Reliability Centered Maintenance (RCM) to identify critical component/parts. It was followed by the Preventive Maintenance Basis (PMB) to collect and document industry "best practices" for the maintenance of equipment. The relationship of the various industry and USNRC programs is shown in Figure 2.

However, the early aging studies and the license renewal efforts quickly pointed to a maintenance gap. Plants did not have, nor were they developing, and long-term aging management programs. As a result, EPRI sponsored the development of a Life Cycle

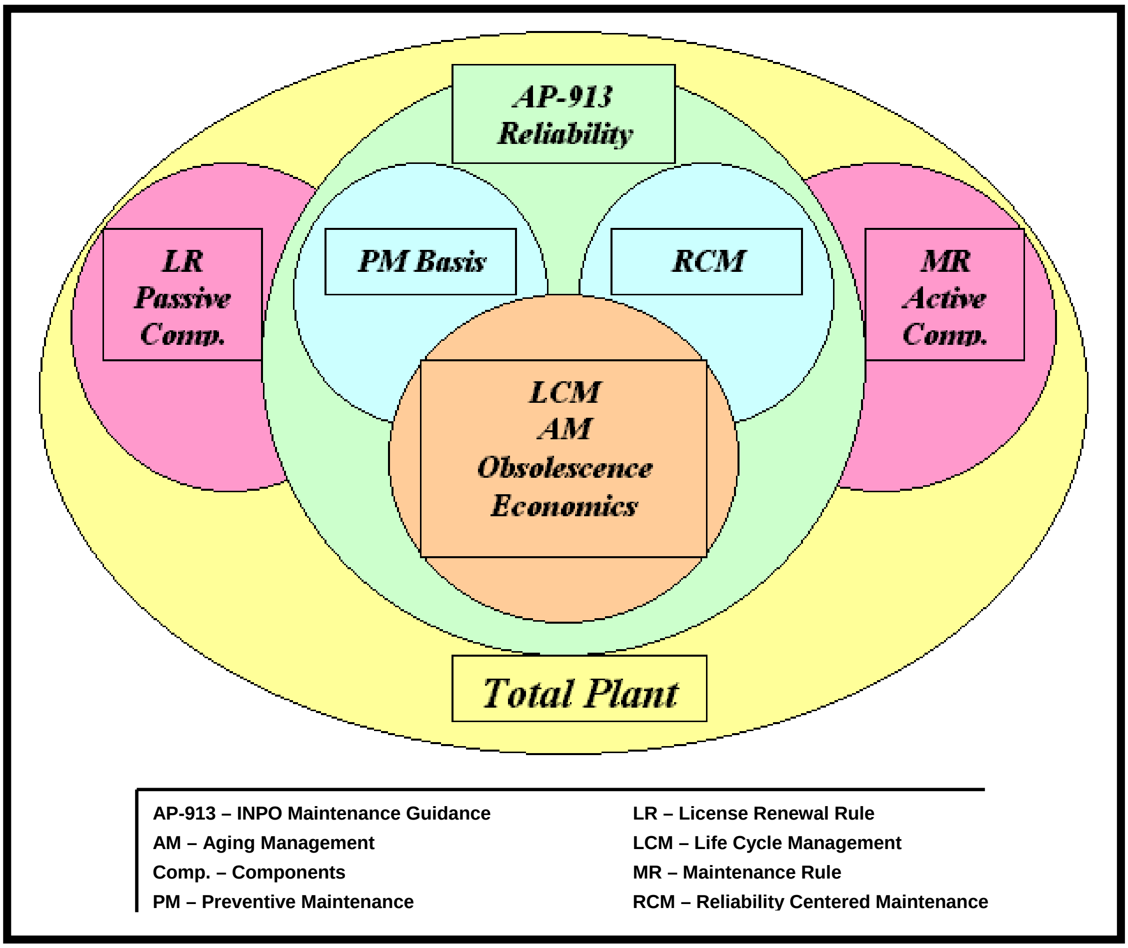

Figure 2: *The Relationship of Aging Management Programs*

Management (LCM) methodology for the plants to use to determine the most effective alternative from a number of scenarios. As defined by AP-913, life cycle management (LCM) is:

> *… the process by which nuclear power plants integrate operations, maintenance, regulatory, environmental, and business activities that manage plant condition (by means of aging and obsolescence management), optimize operating life (including the options of early retirement and license renewal), and maximize plant value while maintaining plant safety.*

LCM can provide a basis for a long-term maintenance strategy with the highest reliability at the least cost. LCM makes use of RCM and PMB in addition to addressing technical obsolescence, aging management and the generic and plant-specific operating experience. The LCM program also considers economics to select the optimum long-term maintenance strategy.

INPO lead the development of the “umbrella” process that incorporates the various maintenance and aging management programs and requirements. This resulting industry guidance document, entitled, *Equipment Reliability Process Description* (AP-913), has become the industry standard by which plant maintenance performance is currently judged.

A related maintenance oversight activity is exercised by the insurance companies, such as Nuclear Equipment Insurance Limited. These insurance companies have created similar maintenance standards to be followed with the objective of minimizing their liability exposure. A benefit-penalty system has been applied by which the insurance premiums are determined based on the level of compliance with their maintenance standards.

The Industry "Umbrella" Program (AP-913)

The *Equipment Reliability Process Description* (AP-913) developed by INPO has become the industry umbrella for effective plant maintenance practices. Many plants have adopted all or portions of AP-913, including the applicable parts of the regulatory programs, such as the aging management and performance monitoring parts of the License Renewal Rule and Maintenance Rule, respectively. It is important to note that the AP-913 is an industry initiative and is not a mandatory requirement. However, INPO's role as an industry oversight organization for utility corporate and plant performance assures that most plants implement part or all of the recommended equipment reliability program guidance.

Large utilities with a substantial number of plants are creating their own organizational standards that essentially mirror the AP-913 program features.

The AP-913 process, as shown in Figure 3, consists of six basic elements. Each element, as briefly described below, has a series of considerations or tasks, which should be part of an effective maintenance program.

<u>**Scoping and Identification of Critical Components**</u>

There are basically three categories of components within the plant. First, and most important, are the critical components that would shut down the plant or initiate safety

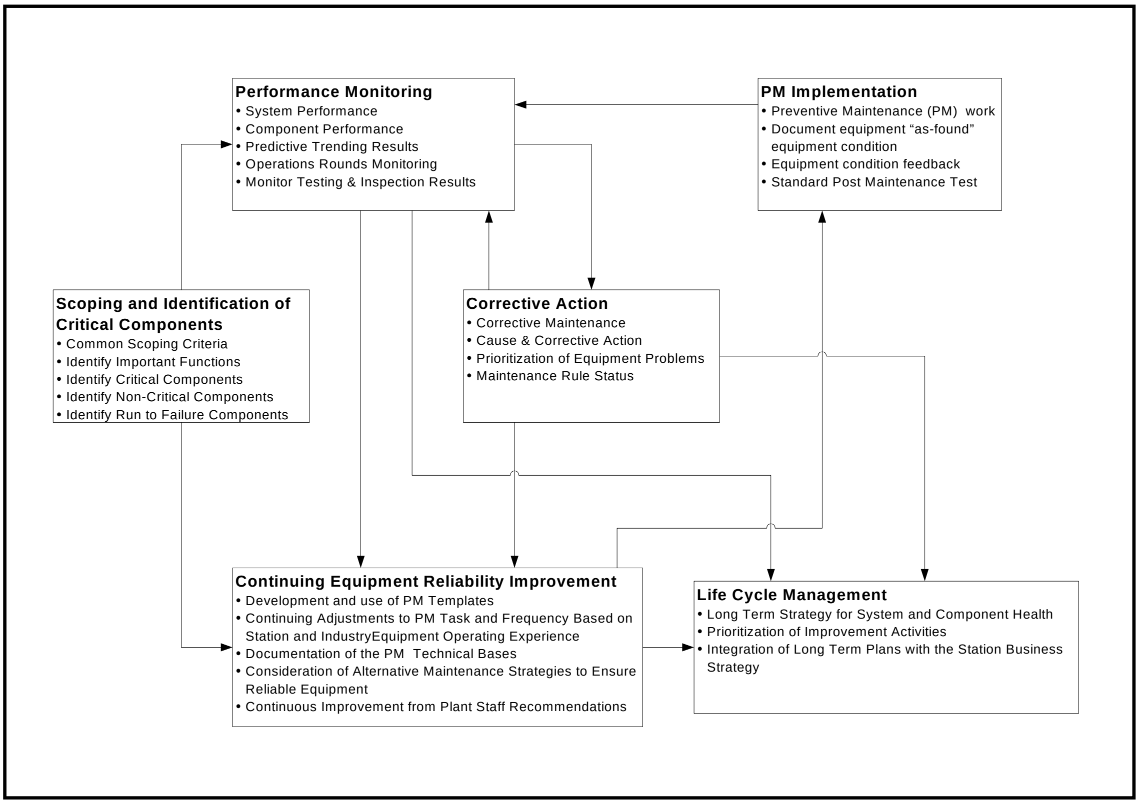

Figure 3: *Equipment Reliability Process (Source: INPO AP-913)*

systems if they were to fail their functions. The second category is the non-critical components that are being maintained by regular or vendor recommended maintenance. The third category is the run-to-failure components for which maintenance is not economically justifiable. These components are replaced on a set time schedule or following their failure.

Performance Monitoring

For the critical and non-critical components, performance monitoring as required by the USNRC Maintenance Rule is applied at the system or component level (reliability and availability). Performance trending is conducted to assure that mitigative or corrective actions are contemplated prior to the component or system exceeding its performance limits.

The routine system of engineer and operator rounds is one example of recommended performance monitoring tasks. The rounds are undertaken frequently (such as daily or weekly) to detect minor changes in equipment behavior. Tasks to be administered during the rounds may include visual observation of the equipment looking for missing/loose parts, leakage, noise, fumes/smell, missing insulation, construction debris, abnormal vibration, discoloration and rusting, deformation, and cracking of foundations. Operators are required to confirm the correct position of breakers and switches, read local instrumentation, and verify position of fire and security barriers/doors.

At the crafts level, a "*condition code*" process has been implemented by most plants to facilitate condition feedback for the equipment being worked on. This condition code typically includes three to five levels of equipment conditions as observed by the maintenance personnel. Typical levels of condition codes may be:

- Condition 1: As New
- Condition 2: Meets or exceeds expectations
- Condition 3: Shows signs of acceptable wear/degradation
- Condition 4: Should be scheduled for overhaul, replacement
- Condition 5: Found in failed condition

These conditions are simple observations and are recorded on a standard form with the work package to be evaluated by the system engineer. A more detailed condition code table, using a 10-point graduation, is included in AP-913 presented in Table 1.

Other recommended considerations for performance monitoring include:

- use of equipment history and the corrective action database to perform equipment failure trending for components used across several systems
- specific alert values for condition-monitoring data in the component performance criteria

Table 1: *Equipment Condition Codes* (Source: AP-913)

CONDITION 1	
	Unanticipated Failure Failure not associated with normal wear or aging discovered at time of activity Condition Report required to address condition Potentially misapplied structure, system, or component requiring engineering resolution
CONDITION 2	
	Repair/Replacement Required, Not Necessarily Due to Normal Wear or Aging Failure not definitely attributable to normal wear or aging; can be repaired with replacement in kind material, parts, or components May require engineering resolution
CONDITION 3	
	Repair/Replacement Required, Due to Normal Wear or Aging Failure that is obviously due to normal wear or aging that can be repaired without engineering evaluation Consider performing the PM task more frequently
CONDITION 4	
	Measured Parameter Outside Specified Tolerance Component has not failed, but adjustment is required No replacement parts other than those dictated by the PM task required Consider performing the PM task more frequently
CONDITION 5	
	Reliability Degraded Component has not failed, but replacement or repairs recommended due to normal wear or aging to ensure reliable operation until the next inspection Consider performing the PM task more frequently
CONDITION 6	
	Measured Parameter Within Tolerance, but Adjustment Required Adjustments required due to normal wear, aging, or drift No replacement parts other than those dictated by the PM task required
CONDITION 7	
	Satisfactory Observed wear considered normal No adjustments required No replacement parts other than those dictated by the PM task required
CONDITION 8	
	Superior Observed wear less than would be expected No adjustments required No replacement parts other than those dictated by the PM task required Consider performing the PM task less frequently
CONDITION 9	
	Like New Component is in “like new” condition Consider performing the PM task less frequently
CONDITION N	
	As-Found Condition Not Applicable Administrative task One-time performance Condition monitoring task

- trending of as-found equipment condition codes to:
    - identify patterns of degradation by component type and the need to adjust preventive maintenance (PM) tasks or frequencies
    - update PM templates based on station equipment operating experience
    - to identify PM outliers for additional evaluation

- use industry event database (EPIX) to identify component trends being experienced by other plants, and take proactive measures to avoid similar failures
- identify aging or obsolescence issues
- evaluate the relationship between component performance and effect on system functional performance
- trend key data collected on operator rounds
- consult non-nuclear sources of component failure information and trending parameters/strategies

Corrective Actions

This is perhaps the most important element, in that it directs the plant to perform a rigorous root cause evaluation of equipment failure. It also requires management actions to develop a plant culture of preventing future failures. According the AP-913:

> *This is one of the hard links management can establish to reinforce an intolerance for unexpected equipment failures. By establishing management expectations that evaluations of unexpected failures include the question of why the failure occurred and what process should have prevented it, instead of just repairing it, continuous equipment reliability improvement initiatives become a way of life. This is also an opportunity to revisit a previous decision to run to failure.*

An evaluation is required to determine if the failure was preventable, using the following considerations:

- What existing barriers should have prevented the failure (procedure completeness, procedure implementation, craft training, post-maintenance testing, tag-out restoration, use of operating experience, troubleshooting, unavailability management, and human performance)?
- What barriers should be implemented to prevent recurrence? Consider the risk/benefit of the change.
- What other components are susceptible to this failure mechanism; what is the extent of this condition?
- How did the continuing equipment reliability improvement process miss this?
- Could more frequent implementation of existing preventive maintenance actions prevent recurrence?
- Should the scope of the preventive maintenance tasks be increased?
- Is there an aging or obsolescence concern that should be addressed in the corrective actions?
- Is additional corrective maintenance needed?
- Is the failed component in USNRC Maintenance Rule scope or did the failure cause a significant power reduction?
- Provide equipment root cause training and qualification, including the requirement to participate in a certain number of root cause analyses per year.

- Develop root cause specialists or mentors, with additional training and experience, in departments that frequently participate in this activity.
- Use a graduated approach for root cause determination commensurate with the level of consequences of the failure. Examples include trending only, apparent cause determination, root cause determination by an individual, and forming a root cause team.
- Establish clear methods to obtain vendor expertise or increased failure analysis for equipment failures whose root cause cannot be determined by a team.
- Search in-house and industry operating experience, including EPIX, to determine if similar failures have occurred.
- Are similar components affected by the same problem?

Continuing Equipment Reliability Improvement

This element is the focus of the INPO equipment reliability strategy. It is structured to reflect a living maintenance program with continuous feedback, enhancements based on equipment performance, adjustments to PM frequencies to compensate for poor or excellent performance, to look for alternative solutions, recognize application of new technologies/diagnostics and to eliminate low value tasks and/or add new tasks where the need arises. Equipment reliability is tightly coupled to the need to identify incipient failures, monitor failures at other plants and look for precursors. This means that we know the locations, susceptibility to failure and the potential degradation, such that effective monitoring methods can be engaged. This element suggests that the following monitoring methods be considered:

- Degradation can be monitored by installed instrumentation.
- Degradation can be detected by a predictive maintenance technique such as vibration, oil sampling, thermography, or motor signature analysis.
- Degradation can be visibly observed during operator rounds or system engineer walkdowns.
- Degradation can be measured by surveillance testing.

Long-Term Planning and Life-Cycle Management

With the event of power uprate (increasing the power output beyond the design levels, e.g., 115 to 120%) and life extension for the nuclear plants, it became evident that long-term plans needed to be developed to support cost-benefit assessments of these major capital projects and to formulate a lifetime maintenance strategy for the plants. The utilities were used to strategic planning with respect to power need forecasts, selecting the type of power generation and revenue projections, however, the nuclear plants needed a more sophisticated asset management tool, taking into account the unique life cycle and major capital expenditures for these plants. The Life Cycle Management (LCM) methodology and process was developed to fit this gap and was subsequently integrated with AP-913. This integration specifically recognizes the need to merge the long-term maintenance strategy with the station business plan.

Preventive Maintenance Implementation

Lastly the program addresses implementation issues of the equipment reliability process. Plants are expected to have a rigorous work order system by which maintenance activities can be scheduled, implemented and recorded. The work order database provides a historic record of all work performed and includes data fields for the type of activity (preventive, corrective, design change, surveillance testing, operations test, etc) for each component, the date, required hours and in many cases also the labor and material costs. The data such constitutes a significant element for the reliability assessment in that the number of failures (each component and all similar components) can be sorted by year, cost and type, from which failure rates can be computed. Trending of the number of preventive and corrective work orders can be performed to ascertain whether the trend is stagnant, positive or negative. The effectiveness of the maintenance program can therefore be measured over time.

The License Renewal Rule

In 1954 the original licensing requirements for US nuclear power plants set a 40-year limit for operating licenses. This 40-year limit was selected based on economic considerations rather than technical limitations. However, even at that time, the Atomic Energy Act was set up to allow renewal of the operating licenses.

In the late 1970s the USNRC and the nuclear industry began to address the issues concerning life extension. The first initiatives were directed at determining whether or not the safe operation of the plant beyond its 40-year operating limit could be technically justified – could the aging effects be adequately managed so the plant could be operated within the original safety margins during the period of extended operation?

To answer this question both the USNRC and the industry initiated a number of aging research programs. One of the largest aging research efforts was the Nuclear Aging Plant Research (NPAR) Program. This 10-year, multi-million dollar effort provided the basis for determining that extended operations were technically justifiable. It also provided the foundation for the license renewal requirements and renewal process.

The NPAR Program identified aging as the cumulative, time-dependent degradation of a systems, structures, and components (SSCs) that, if unmitigated, could compromise continuing safe operation of the plant. Mitigating measures are therefore needed to ensure that aging does not reduce either the operational readiness of a plant's safety systems or the defense-in-depth through common-mode failures of redundant, safety-related equipment.

The main goals of the NPAR Program were to understand aging and to identify ways to manage aging of safety-related SSCs. The specific technical objectives were to:

- identify and characterize aging effects which, if unmitigated, could cause degradation of SSCs and impact plant safety
- develop supporting data to facilitate management of age-related degradation
- identify methods of inspection, surveillance, and monitoring, or of evaluating residual-life of SSCs, which will ensure timely detection of significant aging effects before loss of safety function
- evaluate the effectiveness of storage, maintenance, repair, and replacement practices in mitigating the effects of aging and diminishing the rate and extent of degradation caused by aging
- provide technical bases and support for the License Renewal Rule and the license renewal process

During the mid-1980s the USNRC initiated two other aging assessment programs as companions to the NPAR Program. One focused on the aging of nuclear plant vessels, piping, steam generators, and nondestructive examination techniques. The other involved the assessment of age-related degradation on plant civil structures. These three programs provided a wealth of information and insights on aging and aging management that formed the basis for the License Renewal Rule.

The NPAR Program alone produced over 150 technical reports and numerous papers and proceedings concerning aging characteristics and aging management of safety-related SSCs. The major subjects examined by the NPAR and related aging research programs are shown in Table 2.

Table 2: *Subjects Examined by the NPAR and Related Aging Research Programs*

Air operated valves	Chillers
Auxiliary feedwater pumps	Heat exchangers
Batteries	Large electric motors
Bistables/switches	Main steam isolation valves
Cables	Motor operated valves
Chargers/inverters	Piping
Check valves	Power operated relief valves
Civil structures	Small electric motors
Circuit breakers/relays	Snubbers
Compressors	Solenoid valves
Connectors, terminal blocks	Steam generators
Diesel generators	Transformers
Electrical penetrations	Vessels

Although the aging studies examined SSCs with respect to their operation in the nuclear plants, much of the aging degradation and aging management information is applicable to the petroleum and other industrial sectors. A list of selected aging reports from the NPAR program is provided in Attachment of the CGI Report 06-22, *Condition Monitoring of Passive Systems, Structures, and Components*.

Based on industry initiatives started in 1985, two pilot plants were chosen to conduct life extension investigations and feasibility assessments. The principal objectives were to find answers to a number of questions, including:

- What defines the ultimate life of a plant?
- What are the events that lead to final plant shutdown?
- What is a realistic and achievable operating life?
- What type of repair and replacement capital projects would be required?
- Are there any technical or economic obstacles or limits?

These studies introduced the concept of "critical components". These are components that if they were allowed to degrade unimpeded would constitute a safety concern and lead to shutdown. An importance ranking process was developed to identify the critical components and perform a relative importance ranking, using a Delphi process. The result was a list of the top 24 components, all passive components and structures. These components were then selected for a detailed aging assessment to investigate the plausible aging mechanisms, identify the associated aging effects that have been observed and to formulate a strategy for effective aging management, using preventive and mitigative maintenance or corrective repair and replacement options. These efforts were later extended to cover a host of other components and commodities, including active components, to create a more complete picture of the plant's aging concerns.

While the studies for the two pilot plants were carried out by completely separate research teams, the results and conclusions were very similar. A byproduct of the pilot studies were the identification of a host of additional aging research tasks, a need to better understand certain aging phenomena, the recognition that aging management needs to start at the beginning of the life cycle and the need to perform some maintenance tasks to better monitor material conditions, such as inspections, tests, fatigue cycle counting, measuring environmental conditions in electrical enclosures, testing soil and water for aggressiveness (chlorides, phosphates, pH) with respect to concrete and instituting structures inspections.

A technical review group examined the aging research findings and concluded that many aging phenomena are readily manageable and do not pose technical issues that would preclude life extension for nuclear power plants. They also stated that as long as there are effective inspection and maintenance practices, the plant life is simply limited by the economic cost of repair or replacement of any components that don't meet specified acceptance criteria.

With the technical and economic feasibility of life extension demonstrated, the industry started working with the USNRC to develop a License Renewal Rule that would provide a formal process to allow extended operation beyond the original 40-year license.

In 1991, the safety requirements for license renewal (entitled, *Requirements for Renewal of Operating Licenses for Nuclear Power Plants)* were adopted by the USNRC. These requirements, known as the License Renewal Rule, established the procedures, criteria, and standards governing the renewal of nuclear power plant operating licenses. These were made mandatory requirements as part of the United States Code of Federal Regulations (commonly referred to as 10 CFR Part 54).

The scope of this initial version of the Rule included both passive and active components for the safety related systems of the plant.

Revisions to the Rule – Lessons Learned

Again, the Monticello plant volunteered to be the demonstration plant to test the Rule. The objective was to assess the effectiveness of the requirements and the application and review process. Once completed, it became apparent that the provisions of the original Rule required changing – particularly the requirements for commitments and additional maintenance tasks to be implemented. Cost estimates ranged from to $100 to $500 Million for a plant to comply with rule requirements.

The Rule did not allow sufficient credit for existing programs, particularly those under the USNRC Maintenance Rule, which help manage plant aging phenomena on an on-going basis. The initial License Renewal Rule also did not provide a predictable nor stable process. Industry point out, and the USNRC agreed, that it is essential to have a predictable and stable regulatory process that clearly and unequivocally defines the regulatory expectations for license renewal.

The revised Rule was published in 1995. A copy is provided in Appendix B. The new amended Rule established a regulatory process that is simpler, more stable, and more predictable. It put the focus of the license renewal assessment on the licensees aging management activities concerning passive and long-lived SSCs. It also clarified the focus on managing the adverse effects of aging rather than identification of all aging mechanisms. The changes to the integrated plant assessment (IPA) process were to make it simpler and more consistent with the revised focus on passive, long-lived systems, structures and components.[1]

The relationship of the regulatory requirements for the Maintenance and License Renewal Rules is shown in Figure 4.

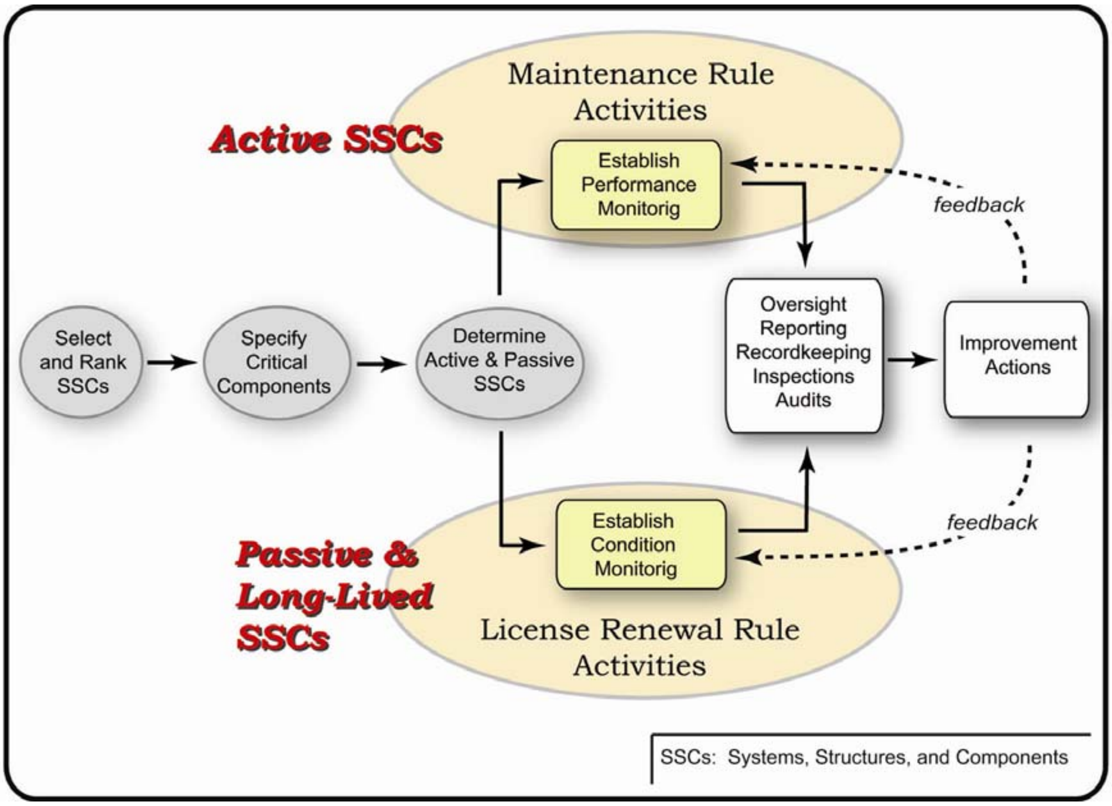

Figure 4: *Relationship of Maintenance and License Renewal Rules*

The License Renewal Process

The license renewal process proceeds along two tracks – one for the review of safety issues and another for environmental issues. The safety requirements, as noted above,

[1] An extensive discussion of the revisions and the USNRC's license renewal philosophy can be found in the Statement of Considerations that accompanied the License Renewal Rule as published in the US Federal Register, Vol. 60, No. 88, page 22461, May 8, 1995.

are addressed in 10 CFR Part 54. The environmental requirements are found in 10 CFR Part 51.

The USNRC developed a generic environmental impact statement (GEIS) which covered impacts that were common to most all nuclear power plants. During the review process the USNRC focuses on the important environmental issues specific to each plant.

The license renewal review process (Figure 5) is intended to identify any additional actions that will be needed to maintain the functionality of the SSCs for the extended operation. The USNRC determined that the following can be excluded from the license renewal aging management review:

- those structures and components that perform active functions
- structures and components that are replaced based on qualified life or specified time period.

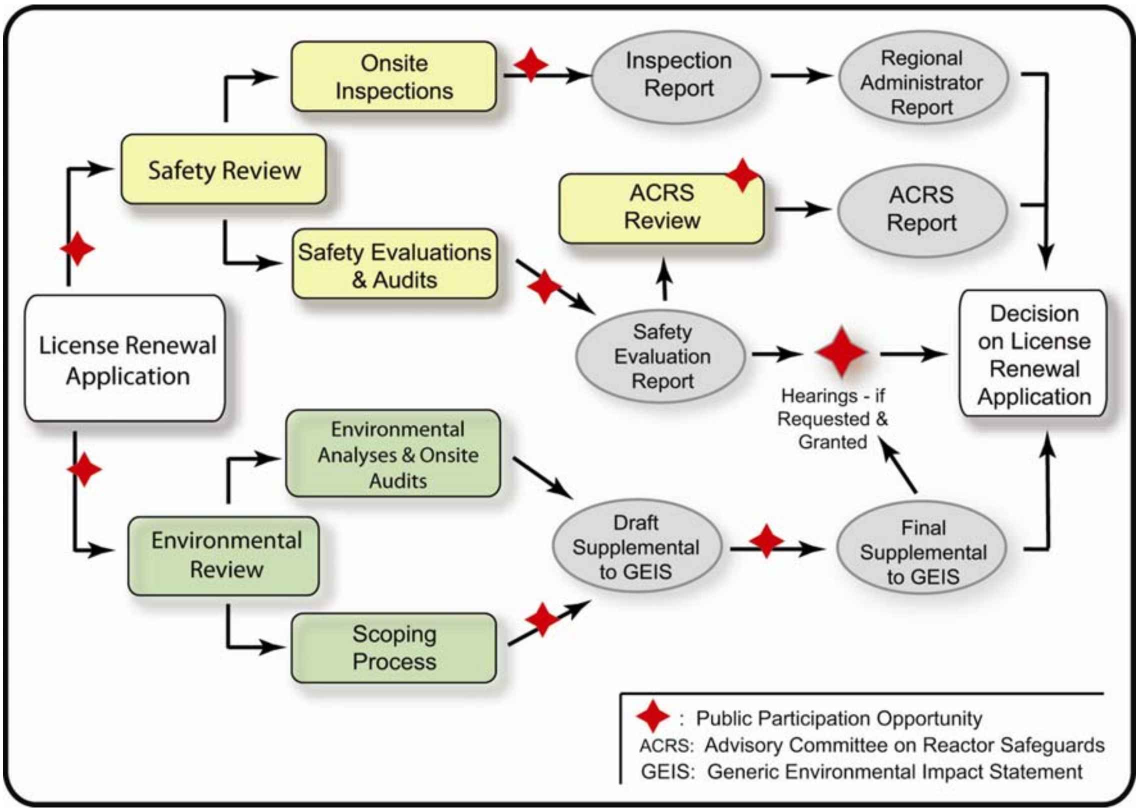

Figure 5: *Simplified Flow Chart of the License Renewal Process (source: USNRC)*

License Renewal Principles

The license renewal requirements for nuclear power plants are based on two key principles:

- the existing USNRC regulatory process (such as the Maintenance Rule) is adequate to ensure that currently operating plants will continue to maintain adequate levels of safety during extended operation – however, license renewal requirements are needed to address age-related degradation unique to life extension for certain passive and long-lived SSCs as well as a few other issues that may arise during the period of extended operation

- each plant's licensing basis is required to be maintained during the renewal term in the same manner and to the same extent as during the original licensing term

The License Renewal Application

Two important items that are required to be included in the application are:

- an integrated plant assessment
- an evaluation of time-limited aging analyses

The application development process involves the following actions:

- identification of the SSCs within the scope of License Renewal Rule
- identification of the intended functions of SSCs
- identification of the structures and components subject to aging management review and intended functions
- assurance that effects of aging are managed
- development and application of new aging management programs and inspections
- identification and resolution of time-limited aging analyses
- identification and evaluation of exemptions containing time-limited aging analyses

Scoping

The scoping phase requires the licensee to identify all plant systems, structures and components that are safety-related or whose failure could affect safety-related functions, or that are relied on to demonstrate compliance with the several specific USNRC's regulations (such as, for fire protection and plant blackout).

The scoping or categorization process can be rather complicated and requires careful review of the nature and function of the various SSCs being considered. For example in the case of valves and pumps, the valve bodies and pump casings may perform an intended function by maintaining the pressure-retaining boundary and therefore would be subject to aging management review.

Integrated Plant Assessment (IPA)

The integrated plant assessment (IPA) is the core of the license renewal application (Figure 6). The purpose of the IPA is to demonstrate that the structures and components requiring aging management (within the scope of the Rule) have been identified and the effects of aging on their functionality will be managed to maintain an acceptable level of safety during extended operations

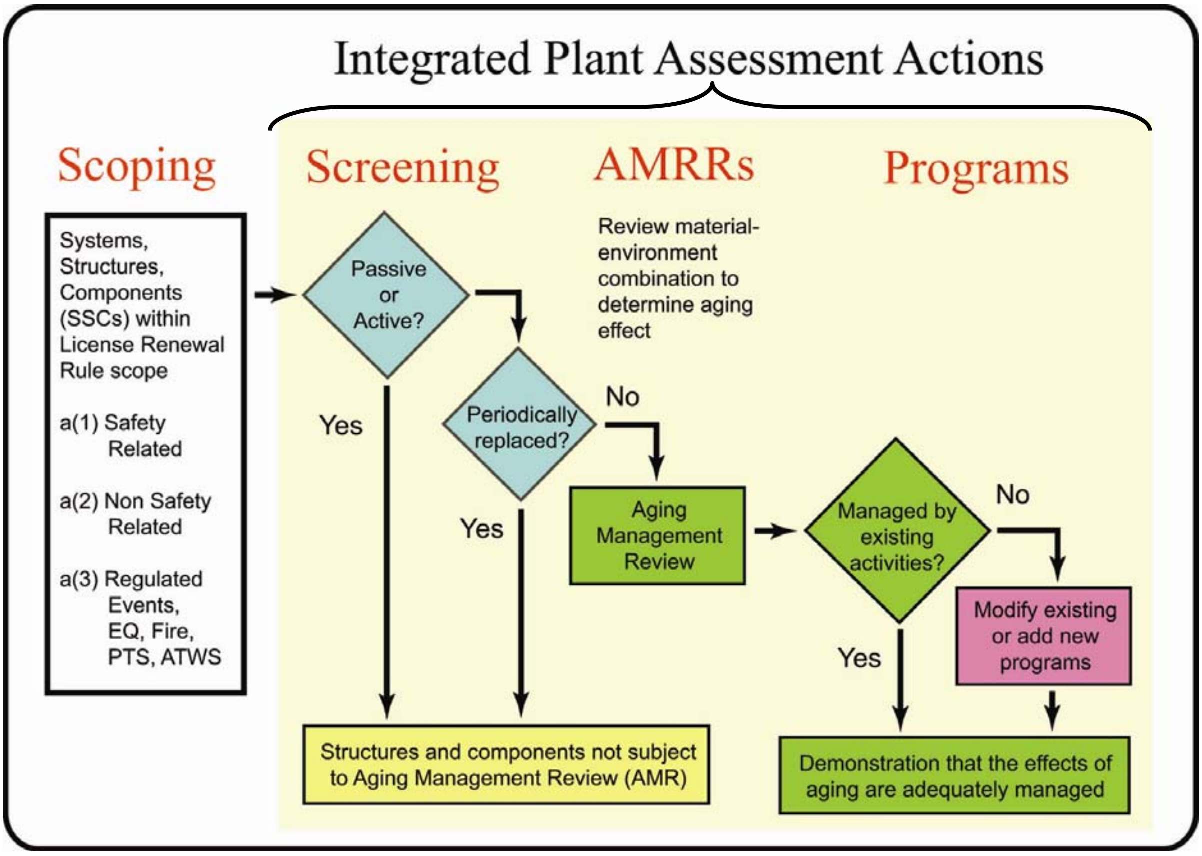

Figure 6: *License Renewal Application Activities*

The first part of the IPA process is to determine which of the structures and components within the scope of the Rule are passive and long-lived. Passive structures and components are those that perform their function without a change in configuration or properties. Long-lived items are those that are not subject to replacement based on a qualified life or specified time period. An example list of such structures and components is provided in Table 3.

The objective of this screening exercise is to determine which components and structures require aging management review to determine whether or not some form of aging management is necessary.

There are a number of different techniques that can be used to identify and assess aging effects. The NEI guidance document (NEI 95-10) lists several approved techniques. These include material-environment-stressors analysis, analysis based on common setting or location, plant specific aging analysis based on loss of intended function, and the use of similar aging management reviews approved by the USNRC.

The licensee must demonstrate that the effects of aging will be managed in such a way that the intended functions will be maintained for the extended operation period. Where the licensee can demonstrate that the existing programs provide adequate aging management throughout the period of extended operation, no additional action may be required. However, if additional aging management activities are warranted, it will be up to the licensee to define these actions. This can include such activities as developing new monitoring programs or increasing current inspections. Licensees should consider all programs and activities associated with the component or structure to determine to what degree they already manage the aging degradation. The four general types of aging management programs are:

- Prevention – to preclude certain levels of aging degradation from occurring (e.g., coating programs to prevent external corrosion of a tank)
- Mitigation – to reduce or slow aging effects (e.g., chemistry programs to mitigate internal corrosion of piping)
- Condition monitoring – to inspect for the presence of and extent of aging effects (e.g., visual inspection of concrete structures for cracking and ultrasonic measurement of pipe wall for erosion-corrosion induced wall thinning
- Performance monitoring – to test the ability to perform its function (e.g., heat balances on heat exchangers for the heat transfer intended function of the tubes)

Table 3: *Examples of Structures and Components included in, or excluded from, the License Renewal Rule Scope* (Source: 10 CFR 54)

Passive Structures & Components Included in Rule Scope (Example List)	**Active Structures & Components Excluded from Rule Scope (Example List)**
cable trays component supports containment containment liner core shroud electrical and mechanical penetrations electrical cabinets electrical cables and connections equipment hatches heat exchangers piping pressure retaining boundaries pressurizer pump casings reactor coolant system pressure boundary reactor vessel seismic Category I structures steam generators valve bodies ventilation ducts	air compressors batteries battery chargers breakers circuit boards cooling fans diesel generators motors power inverters power supplies pressure indicators pressure transmitters pumps (except casing) relays snubbers switches switchgears the control rod drive transistors valves (except body) ventilation dampers water level indicators

To assist the licensees in perform their plant-specific aging assessments and avoid duplication of work from one plant to another the USNRC developed a comprehensive guidance document entitled, *Generic Aging Lesson Learned Report* (GALL) NUREG-1801. The document provides aging management matrixes for the various passive mechanical, electrical and structural components found in a nuclear plant. The GALL report also provides links and references to acceptable aging management programs inclusive of specific program attributes. An example of a typical aging matrix from the GALL report is shown in Table 4.

Table 4: *Typical Aging Matrix from GALL Report* (Source NUREG-1801)

VII AUXILIARY SYSTEMS
C1 Open-Cycle Cooling Water System (Service Water System)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.C1-14 (AP-59)	VII.C1.	Piping, piping components, and piping elements	Stainless steel	Lubricating oil	Loss of material/ pitting, crevice, and microbiologically influenced corrosion	Chapter XI.M39, "Lubricating Oil Analysis" The AMP is to be augmented by verifying the effectiveness of the lubricating oil analysis program. See Chapter XI.M32, "One-Time Inspection," for an acceptable verification program.	Yes, detection of aging effects is to be evaluated
VII.C1-15 (A-54)	VII.C1.2-a VII.C1.6-a VII.C1.1-a VII.C1.4-a	Piping, piping components, and piping elements	Stainless steel	Raw water	Loss of material/ pitting and crevice corrosion, and fouling	Chapter XI.M20, "Open-Cycle Cooling Water System"	No
VII.C1-16 (AP-56)	VII.C1.	Piping, piping components, and piping elements	Stainless steel	Soil	Loss of material/ pitting and crevice corrosion	A plant-specific aging management program is to be evaluated.	Yes, plant-specific
VII.C1-17 (AP-30)	VII.C1.	Piping, piping components, and piping elements	Steel	Lubricating oil	Loss of material/ general, pitting, and crevice corrosion	Chapter XI.M39, "Lubricating Oil Analysis" The AMP is to be augmented by verifying the effectiveness of the lubricating oil analysis program. See Chapter XI.M32, "One-Time Inspection," for an acceptable verification program.	Yes, detection of aging effects is to be evaluated

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The licensee has a choice to utilize the generic findings of the GALL report as a technical basis for his plant, subject to verification of applicability. If the plant-specific conditions, materials, components or aging management programs are different, a plant-specific assessment is required. The GALL report relies heavily on a condition directed maintenance program (inspection, analysis and testing) for effective aging management that is to monitor the material conditions.

The aging management programs to be credited for license renewal, must meet a rigorous 10-point acceptance criteria shown in Table 5.

The GALL Report includes a comprehensive listing of all the plausible aging effects and mechanisms, with a definition and explanation of applicability. The basis for these aging effects and mechanisms are contained in the numerous references form the wealth of the aging research conducted by the industry, EPRI, DOE, and the USNRC. With the exception of a few industry-specific or unique degradation mechanisms, these aging effects and mechanisms are applicable to almost any industrial facility and are not specific to power plants. An edited version was extracted from the GALL report is provided in Appendix B.

The last important tool provided with the GALL report, is a series of aging management programs (AMPs), targeting the specific aging mechanisms and affected materials. Licensees are expected to implement these aging management programs as part of their maintenance program without much deviation. If plant-specific changes are required, they must be identified to the USNRC for approval. Each of the aging management programs has been developed with substantial industry input to reflect current aging

Table 5: *Aging Management Activity Program Elements* (Source, NUREG-1801)

Element	Description
1. Scope of the activity	Scope of the program/activity should include the specific structures and components subject to an aging management review for license renewal.
2. Preventive actions	Preventive actions should mitigate or prevent aging degradation.
3. Parameters monitored or inspected	Parameters monitored or inspected should be linked to the degradation of the particular structure or component intended function(s).
4. Detection of aging effects	Detection of aging effects should occur 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 and timing of new/one-time inspections to ensure timely detection of aging effects.
5. Monitoring and trending	Monitoring and trending should provide predictability of the extent of degradation and provide timely corrective or mitigating actions.
6. Acceptance criteria	Acceptance criteria, against which the need for corrective action will be evaluated, should ensure that the structure or component intended function(s) are maintained under all current licensing basis design conditions during the period of extended operation.
7. Corrective actions	Corrective actions, including root cause determination and prevention recurrence, should be timely.
8. Confirmation processes	Confirmation processes should ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective.
9. Administrative controls	Administrative controls should provide a formal review and approval process.
10. Operating experience	Operating experience of the aging management activity, including past corrective actions resulting in program enhancements or additional programs or activities, should provide objective evidence to ensure that the effects of aging will be adequately managed so that the intended functions of the structure or component will be maintained during the period of extended operation.

management practices and to maintain effectiveness. There are 39 AMPs for mechanical component aging management, eight structural programs and six electrical programs. An example of an aging management program for concrete structures is provided in Appendix D.

As with the aging mechanisms and aging effects, the AMPs are equally applicable to other industrial facilities, with perhaps a minimized formality and quality control.

Much of the contents contained in the GALL report are repeated in a companion document called the License Renewal Standard Review Plan (SRP-LR), NUREG-1800. This document is for the use by the USNRC staff to assist in the review of the License Renewal applications and to assure consistency among the reviewers. The SRP-LR also provides guidance regarding components, aging mechanisms and aging effects not addressed in the GALL but which require plant-specific aging evaluations.

While the aging management programs are not mandatory, they represent one acceptable method to perform effective aging management under the license renewal rule. Licensees may deviate and apply their own versions. However, such programs are subject to acceptance by the USNRC and usually require a substantial justification to deviate from the standards. In this way, the AMPs constitute a near-mandatory status and the specific activities referred to the programs, become licensing commitments for the extended operating period. For components that are not covered by the GALL report or for which no standard AMPs are applicable, the applicant must perform a detailed documented aging management review.

For the typical plant, the aging management review resulted in the identification of about 200 to 400 specific aging management activities. The activities range from completely new programs to changes to existing programs (scope for additional components, more frequent inspections, different technology, new locations, etc) and administrative tasks to document activities, quality control and training. Most of the impact comes from the additional inspections and testing requirements to monitor the degradation and engineering analyses to demonstrate that existing design margins have not eroded and are adequate for the extended operating period. Examples of updated and new aging management activities and programs are shown in Table 6.

TABLE 6: *Typical New and Updated Aging Management Activities and Programs*

Updated Programs (examples):	New Programs (examples):
Boric Acid Corrosion Prevention Program	Alloy 600 Aging Management Program
Fire Protection Program	Buried Piping Inspection Program
Instrument Air Quality Program	Cast Austenitic Stainless Steel (CASS) Evaluation Program
Maintenance Program	Heat Exchanger Monitoring Program
Service Water System Reliability Program	Cable Management Programs
Structures Monitoring	Reactor Vessel Internals Programs
System Testing Program	Small Bore Piping Program
System Walkdowns Program	Wall Thinning Monitoring Program
	Water Chemistry Control - Chemistry One-Time Inspection Program

Time Limited Aging Analysis

One of the major provisions of the Rule is the identification and analysis of Time Limited Aging Analyses (TLAA). The licensee must identify and update time-limited aging analyses. During the design phase for a plant, certain assumptions about the length of time the plant will be operated are incorporated into design calculations for various SSCs. In order to obtain approval for a renewed license, these calculations must be shown to be valid for the period of extended operation, or the affected SSCs must be included in an appropriate aging management program.

In essence, the USNRC requires the licensee to go back to the original plant design documents and determine if the design criteria included specific time limited assumptions or criteria. Once identified, the original calculations or qualification tests must be updated for the new extended operating life. This process may be a simple ratio method to establish a new value for fatigue cycles, or it may involve a complex fatigue analysis, considering the used-up cycles and extended operating life.

A comprehensive review was performed by the industry to identify potential time limited aging analyses (TLAAs) that may be part of the original design basis, the underlying design codes and standards, and the qualifications tests (i.e. environmental exposure of cables, corrosion tests) that were performed in support of the original design life calculations. The principal issues identified by this industry review are (NUREG-1800 & NEI-95-10):

- reactor vessel neutron embrittlement
- prestressed concrete containment tendon prestress
- metal fatigue
- environmental qualification of electrical equipment
- metal corrosion allowance
- inservice flaw growth analyses
- inservice local metal containment corrosion
- high-energy line break postulated on fatigue cumulative usage factor

Once the licensee has identified their specific TLAAs, analysis must be performed to extend the design basis for the extended operating period or compensatory measures must be implemented. The licensee must demonstrate one of the following:

- The analyses remain valid for the period of extended operation or;
- The analyses have been projected to the end of the extended period of operation; or
- The effects of aging on the intended function(s) will be adequately managed for the period of extended operation.

These options clearly include full or partial replacement of the component, requalification by testing, more sophisticated analyses (i.e. finite element analysis and fracture mechanics) or use of mitigative measures to impede or avoid degradation. Some plants have chosen to implement stricter preventive and predictive maintenance, one-time inspections to assess used-up margins, monitoring of the environments to recalculate cable life, new inspections to quantify degradation and installation of coupons to monitor corrosion and cracking.

The Maintenance Rule

Because active components in mechanical and electrical systems are normally operating, their performance can be monitored and trended to detect incipient degradation. Representative parameters that can be measured must be established for both the local components and for the complete system. Examples of local component parameters include flow, differential pressure, vibration, and delta temperature. Reliability and availability are examples of typical system performance parameters.

Within the nuclear power generation industry in the United States, the US Nuclear Regulatory Commission (USNRC) has promulgated a "Maintenance Rule" for the purpose of improving the performance monitoring of critical systems at all nuclear power plants in the United States.

Regulatory Requirements

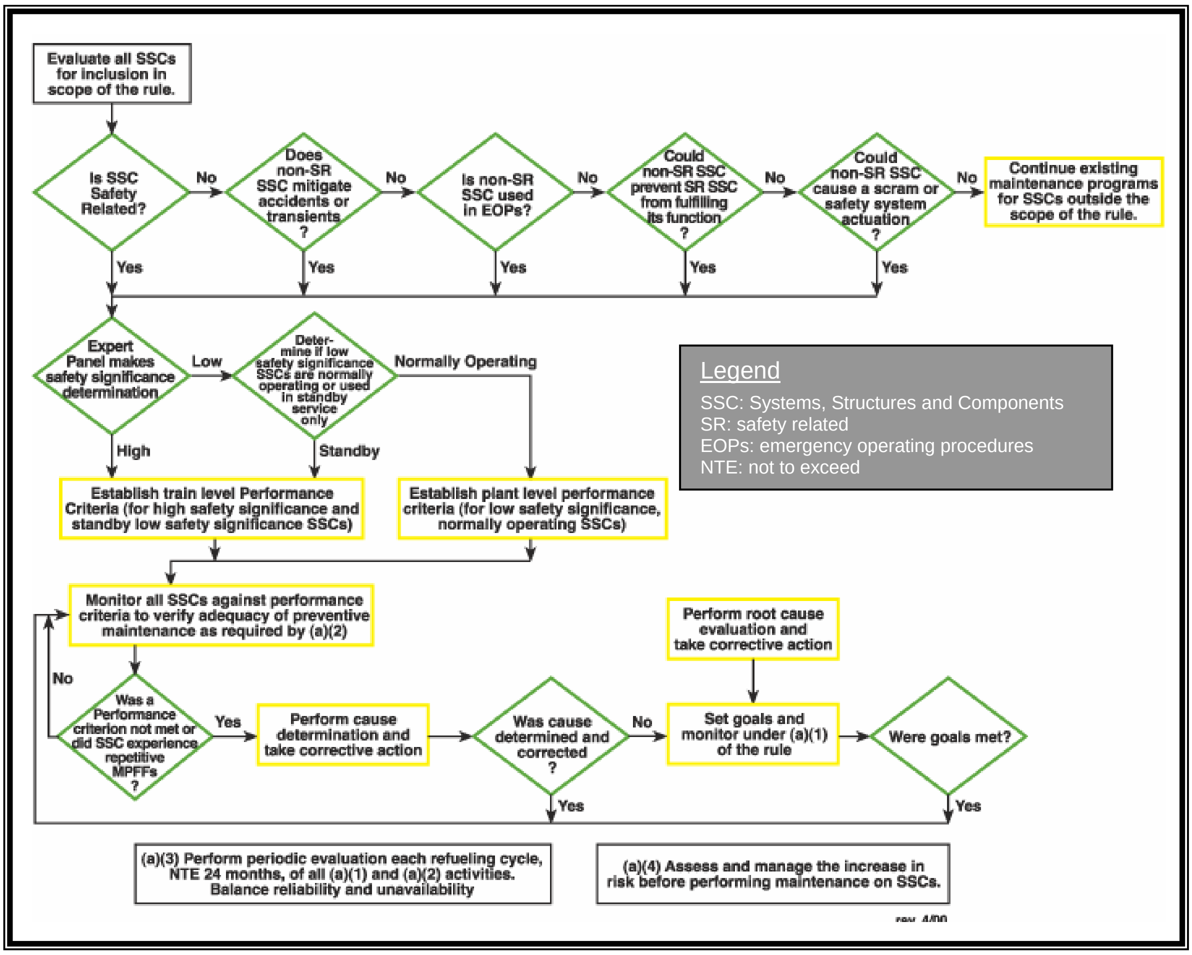
During the 1980s, the USNRC became concerned with the maintenance of nuclear power plants and the attendant decline in reliability. No regulatory provisions were in force to require uniform application of maintenance, except for the Technical Specifications, which required periodic surveillance testing, and the ASME Code, which required periodic inspections of the safety-related pressure boundary components. With the assistance of a number of volunteer plant owners, the USNRC conducted a survey of utility practices in an effort to establish the effectiveness of various maintenance programs (i.e. experience based, vendor recommended, preventive, corrective, run-to-failure), allocation of utility resources among safety and non-safety (power production) equipment and utility methods of monitoring and benchmarking performance. The survey results led the USNRC to conclude that more consistent and rigorous monitoring and reporting of individual system performance parameters was needed. Using industry input, to the USNRC developed a performance-based regulation that would allow individual plants to define the scope of the program, the performance parameters and the acceptance criteria. The plant specific application and implementation would be subject to inspection by the USNRC. The original Rule was issued in July 1991 and became effective in July of 1996 and the USNRC began their implementation inspections. The Rule was revised a number of times to incorporate lessons learned, clarifications and new requirements.

The Maintenance Rule Provisions

The Maintenance Rule was issued under the United States Code of Federal Regulations. This is a mandatory rule that all commercial nuclear power plants must follow. A copy of the full text of the Maintenance Rule is provided in Appendix A. Although the Rule consists of only a single page, the underlying documentation, interpretations, and guidance reports amounts to thousand of additional pages of material and information.

The Maintenance Rule analysis process is shown in Figure 7.

Figure 7: *Simplified Flow Chart of the Maintenance Rule* (Source: USNRC)



The key provisions of the Rule are:

- defining systems monitoring requirements
- preventive maintenance versus availability/reliability
- corrective action goal setting
- operating experience considerations
- demonstrations of preventive maintenance (PM) effectiveness
- bi-annual performance reviews
- quantification of on-line risk

Systems Monitoring Requirements

The Rule makes a significant distinction between important systems that need to be performance monitored at the train level and those systems that can be monitored at the plant level. The systems that are considered to be safety significant with equally or diversely redundant safety systems typically have two or three trains or channels.

Standby systems (systems that are activated in response to an accident or fire or are required to mitigate accident consequences) are monitored using reliability as a performance parameter. Reliability can be measured by such indicators as fail-to-start or fail-to-run per 100 attempts.

Normally operating systems are monitored using availability as a performance measure. Availability is determined as the fraction of system available hours during the mission time divided by the mission time. When assessing reliability and availability, the success or ability of accomplishing the defined safety functions is considered. This permits some level of degradation, as long as the system's functions are not compromised.

Preventive Maintenance versus Availability/Reliability

The Rule recognizes the conflict between performing preventive (invasive) maintenance that requires the system or component to be removed from service and the need to maintain satisfactory availability and/or reliability. One of the requirements mandates that an adequate balance of the two be maintained and reported.

Corrective Action Goal Setting

If a system cannot meet its performance criteria over a period not exceeding 24 months, corrective action is required and a new and more specific performance criteria must be established (Goal Setting) to demonstrate that the corrective action has been effective. This Goal Setting assures that recurring problems are fixed.

Operating Experience Considerations

Operating experience must be considered when establishing the performance parameters and criteria. This experience may be based on generic industry experience or the historical plant performance, failure rates, or reliability / availability values assumed in the plant's probabilistic risk analysis (PRA).

Demonstrations of PM Effectiveness

Systems that are monitored at the plant level require demonstration that the preventive maintenance programs are effective. Plant level performance criteria can include repetitive failures, plant shutdowns, initiation of safety systems and lost production. If the established criteria levels are exceeded, the system must be elevated to "system level monitoring".

System level monitoring requires that an elevated level of monitoring must continue until it can be demonstrated that the system has achieved its new system level performance, before the system is returned to plant level.

Bi-Annual Performance Reviews

The result of the system monitoring and trending activities is subject to bi-annual review to highlight the:

- performance problems
- corrective actions taken
- changes in performance parameters or criteria

- assessment of the balance between maintenance outages and system availability
- evaluation of industry operating experience

The evaluation of industry operating experience is an attempt to identify precursors or incipient failures that may have occurred at other plants and may have generic implications.

<u>Quantification of On-Line Risk</u>

A new paragraph was added to the Rule in 2000 to address the risk associated with plant configuration changes made during operation. This includes systems that are taken out-of-service for maintenance or due to failure/degradation. The on-line risk is influenced by the importance of the unavailable system, the period of time that it is not available, as well as the status of other safety related systems. As a consequence, the USNRC now requires that the on-line risk must be quantified to support continued operation of the plant.

Modifications/Improvements to the Rule

Following the original issue of the rule in 1991, the Nuclear Energy Institute (NEI) formed a utility task group to develop an industry guide, NEI-93-01, to assist the plants with the implementation. The USNRC conducted a number of early plant implementation audits in 1996 and based on these audits it was determined that some interpretations and improvements were desirable. The nuclear industry, represented by the Nuclear Energy Institute (NEI), discussed the implementation issues with the USNRC and subsequently generated a Revision 1 to NEI-93-01 in 1996.

The USNRC reviewed the revised NEI-93-01 for generic acceptability. In 1997 the guide was endorsed with some additional provisions (USNRC Regulatory Guide 1.160 Revision 2). The most significant addition was the inclusion of structures including concrete and steel structures that house or protect equipment covered within the scope of the Rule.

In 2000 the Rule was modified again to address on-line risks associated with maintenance activities. The USNRC added a new paragraph A-4 that then required the NEI to revise NEI-93-01. The new Section 11 provides guidance to the industry on how best to assess on-line risk associated with their maintenance activities. The USNRC endorsed the changes to NEI-93-01 in the USNRC Regulatory Guide 1.180.

Regulatory Inspections and Guidance

The USNRC started plant-specific inspections and audits in 1996 and 1997 to verify the acceptability of methods and procedures and the programmatic approaches taken. Because the rule is performance based, these inspections were unique and required substantial guidance and training of the inspector teams. The training guides and inspection procedures were made available to the industry. This allowed self-assessments and readiness reviews to be conducted prior to USNRC on-site inspections. Lessons learned from the inspections were communicated to the industry in a number of workshops and seminars.

Monitoring Issues

Monitoring important systems at the train level is considered an effective way to identify poorly performing equipment. A redundant high performance train could otherwise shadow the poorly performing train. Performance monitoring at the train or channel level is therefore mandated for risk significant systems. The USNRC was also concerned that generic problems in cross-system component groups (valves, motors, pumps, solenoids) would not be readily identified. As a result all plants are now tracking functional failures, which are periodically reviewed to identify trends of multiple component failures. A definition for a "Repetitive Functional Failure" was crafted to include: "Failures of another same component with identical cause".

Determining meaningful performance parameters for structures became a difficult task. A "Structures Monitoring Program" was created and implemented to periodically inspect (i.e. five to ten year intervals) for functional degradation. The acceptance criteria were defined in the American Concrete Institute (ACI) standards or the American Institute of Steel Construction (AISC) standards. If performance problems are identified, corrective action is required and the structure must be re-inspected at shorter intervals until it can be demonstrated that the fix was effective.

Industry Aging Management Programs (PM Basis and LCM)

The EPRI PM Basis Program

Recognizing the license renewal and maintenance rules as effective aging management tools for the safety-related systems and components in the plants, the industry needed to develop commensurate programs to be applied for the traditional part of the plants, the power production equipment. It is obvious that these systems must also undergo a transformation to support an extended operation. The first of these comprehensive efforts was the development of the Preventive Maintenance Basis Program (PM Basis) by EPRI to cover the majority of generic components and commodities found in the plants. The objective was to research and document the "Industry Best Practices" with respect to effective maintenance and aging management practices. Previously, plant maintenance was largely based on the equipment vendor recommendations, often without a solid technical basis for the requirements, except to protect the equipment warranty provisions.

Table 7: *EPRI PM Basis Component Listing* (Source EPRI TR106857)

Component Description	Volume
Air Operated Valves	V1
Medium Voltage Switchgear	V2
Low Voltage Switchgear	V3
Motor Control Centers	V4
Check Valves	V5
Motor Operated Valves	V6
Solenoid Operated Valves	V7
Low Voltage Electric Motors (600V and below)	V8
Medium Voltage Electric Motors (between 1kV and 5kV)	V9
High Voltage Electric Motors (5kV and greater)	V10
Direct Current Electric Motors	V11
Vertical Pumps	V12
Horizontal Pumps	V13
Reciprocating Air Compressors	V14
Rotary Screw Air Compressors	V15
Power Operated Relief Valves - Solenoid Actuated	V16
Power Operated Relief Valves - Pneumatic Actuated	V17
Pressure Relief Valves - Spring Actuated	V18
HVAC - Chillers and Compressors	V19
HVAC - Dampers and Ducting	V20
HVAC - Air Handling Equipment	V21
Inverters	V22
Battery Chargers	V23
Battery - Flooded Lead-Acid	V24
Battery - Valve-Regulated	V25
Battery - Nickel-Cadmium (NICAD)	V26
Liquid-Ring Rotary Compressor and Pump	V27
Positive Displacement Pumps	V28
Relays- Protective	V29
Relays- Control	V30
Relays- Timing	V31
Heat Exchangers	V32
Feedwater Heaters	V33
Condensers	V34
Main Feedwater Pump Turbines	V35
Terry Turbines	V36
Main Turbine EHC Hydraulics	V37
Transformers- Station Type Oil Immersed	V38
I&C Components	V39

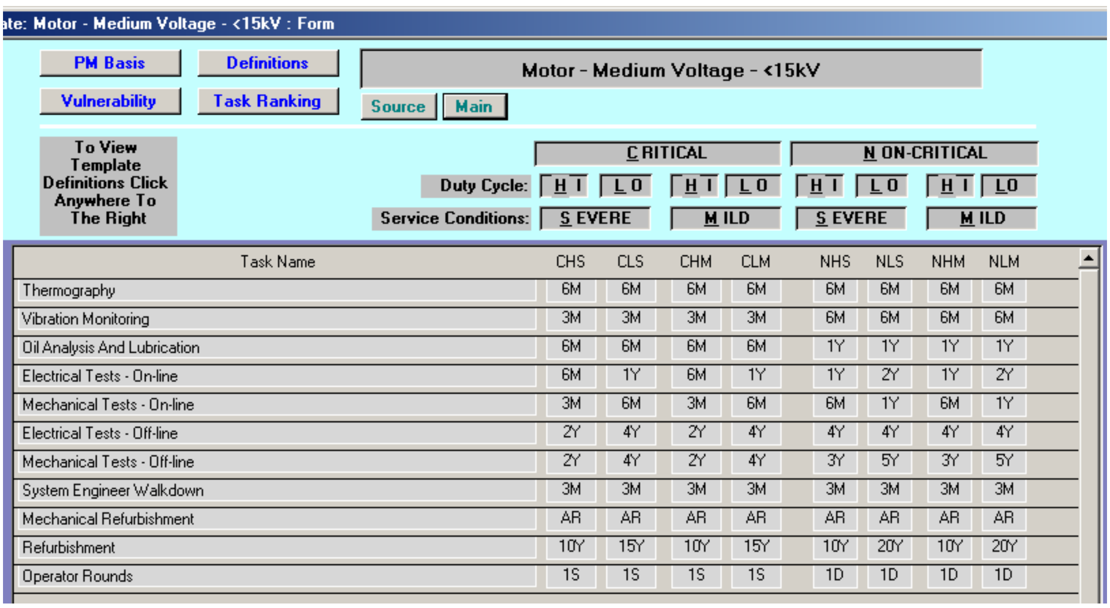
The PM Basis program initially included 39 component templates, each documented in a separate report volume (see Table 7). The program scope was later expanded to add a variety of instrumentation groups. For each component, the program determined the appropriate maintenance activities, the recommended frequency for the activity and the effectiveness of the action. The program also provided a first attempt at correlating PM frequency with reliability, i.e. the more often a component is tested or inspected, the more reliable it is supposed to be and the corollary, what is the reliability reduction if the PM task is eliminated. In many cases, a single task will not provide a major improvement in reliability, but a combination of PM tasks can make a major difference.

In addition to the individual component reports, EPRI converted the templates to electronic format, so that they can be accessed via computer and component reliability manipulations can be exercised on the ACCESS based software. The best practices are captured on a summary template for each component. The templates recognize the fact that not all components are of equal importance and therefore the level of preventive maintenance may be significantly different, dependant on the components service duty, environmental exposure and functional importance. The different levels of recommended PM for the various categories (there are eight different categories to choose from) are shown on the templates. An example template for large electric motors is shown in Figure 8.

The Life Cycle Management Planning (LCM) Process

The Life Cycle Management planning methodology was developed under EPRI and utility sponsorship to create a tool for the long-term maintenance planning, using both, technical and economic measures to find the maintenance plan that will give the highest reliability at the lowest cost. The LCM process is fairly complex in that it requires a relatively accurate representation of the plant’s historic performance, component failures, failure consequences, such as lost power generation, regulatory scrutiny, corrective maintenance costs, and the impact of a poor plant performance on the corporate image and financial picture. However, given the eventual possibility that the

Figure 8: *EPRI PM Basis Template Example*


ate: Motor - Medium Voltage - <15kV : Form

PM Basis | Definitions | Vulnerability | Task Ranking | Source | Main

Motor - Medium Voltage - <15kV

To View Template Definitions Click Anywhere To The Right

	CRITICAL				NON-CRITICAL			
Duty Cycle:	HI	LO	HI	LO	HI	LO	HI	LO
Service Conditions:	SEVERE		MILD		SEVERE		MILD	
Task Name	CHS	CLS	CHM	CLM	NHS	NLS	NHM	NLM
Thermography	6M	6M	6M	6M	6M	6M	6M	6M
Vibration Monitoring	3M	3M	3M	3M	6M	6M	6M	6M
Oil Analysis And Lubrication	6M	6M	6M	6M	1Y	1Y	1Y	1Y
Electrical Tests - On-line	6M	1Y	6M	1Y	1Y	2Y	1Y	2Y
Mechanical Tests - On-line	3M	6M	3M	6M	6M	1Y	6M	1Y
Electrical Tests - Off-line	2Y	4Y	2Y	4Y	4Y	4Y	4Y	4Y
Mechanical Tests - Off-line	2Y	4Y	2Y	4Y	3Y	5Y	3Y	5Y
System Engineer Walkdown	3M	3M	3M	3M	3M	3M	3M	3M
Mechanical Refurbishment	AR	AR	AR	AR	AR	AR	AR	AR
Refurbishment	10Y	15Y	10Y	15Y	10Y	20Y	10Y	20Y
Operator Rounds	1S	1S	1S	1S	1D	1D	1D	1D

plants will operate for 60 years or longer, it was necessary to change the maintenance planning horizon and to be able to forecast major capital projects with respect to timing and cost for the foreseeable future. The following is a quote taken from the EPRI summary report for LCM planning:
"Life Cycle Management planning is intended to provide an effective long-term planning tool for minimizing unplanned capability loss and optimizing maintenance programs and capital investments consistent with plant safety and an identified plant operating strategy. Such an operating strategy might include license renewal and/or plant power uprating. An LCM Plan addresses such issues as aging management, preventive maintenance, obsolescence, and the replacement or redesign of a structure, system or component (SSC) important to safety and plant operation. In short, LCM Planning is viewed as a viable process to systematically identify and examine the important SSCs, optimize their contribution to plant performance, reliability, safety and value, and prepare long-term maintenance management plans and resource projections."

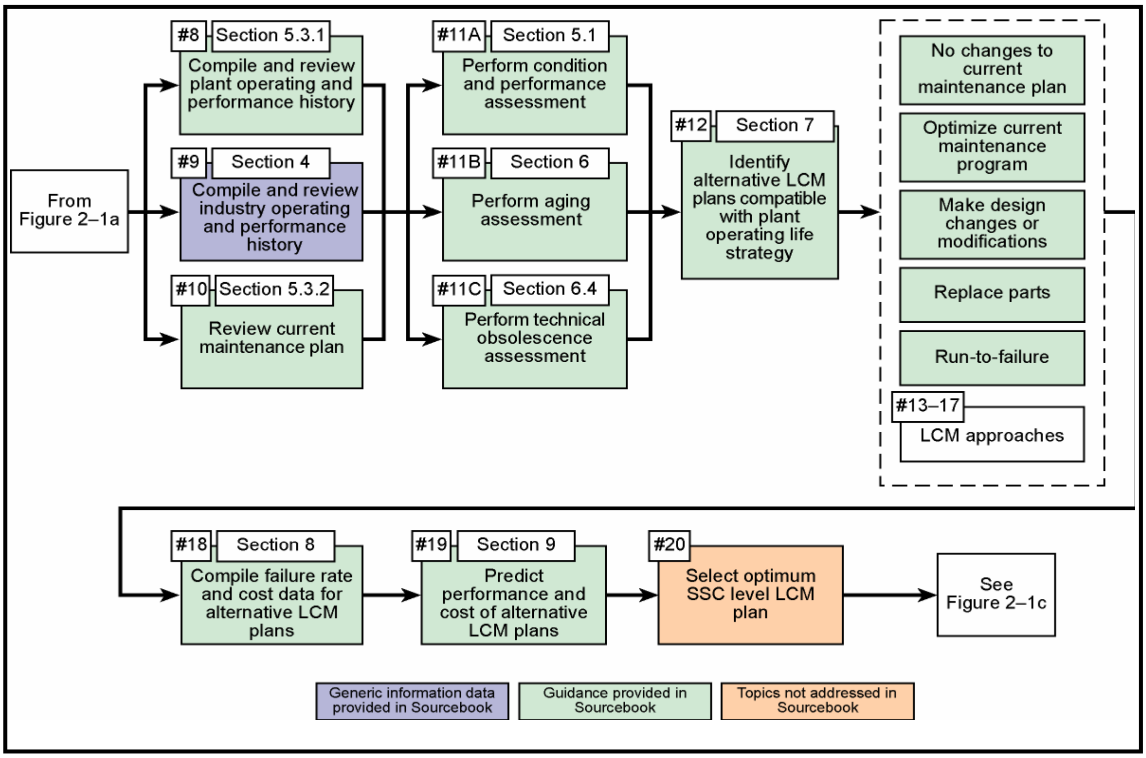
The basic steps of the LCM process are delineated on the simplified diagram, shown in Figure 9. The major steps are briefly reviewed to help understand the interrelationship and task objectives.

<u>Compiling Performance and Operating History</u>

Some plants have included cost data in their WO database, which when trended over time, provides an additional parameter to measure maintenance effectiveness. More money does not always lead to better reliability. To benchmark the plant's performance, similar operating data, including generic failure rates, is assembled from the EPIX

Figure 9

LCM Planning Flowchart – Technical and Economic Evaluation



database and other sources (such as the French EDF Eireda database). Benchmarking has the principal objective to place the specific plant performance relative to its peers. If the plant experiences a failure rate of twice the industry average, there is ample room for improvement and investments are economically justified. If the plant turns out to be already a leader in performance, additional improvements are difficult to sell.

Another aspect of this performance compilation task is the review of the plant's maintenance programs and procedures and to compare the list with the industry "Best Practices", such as the EPRI PM Basis Templates, to identify specific shortcomings and gaps that can be closed to enhance the plant performance.

Condition Assessment

In order to establish a baseline for the plant's equipment performance and reliability, the operating history over the last 5 to 10 years is reviewed and trended. Typically, the plant will have a work order database from which the preventive and corrective work orders can be accessed. A simple count per year will provide a meaningful trend to see if the maintenance activities are increasing, decreasing or portray a stable trend. Also, the ration of preventive to corrective work orders will provide some indication for a successful maintenance program (corrective work orders are decreasing), or the trend will point to problems, that is failures are increasing as an indication of progressive aging problems.

The age of the plant can have a profound effect on the performance and condition of its components; therefore it is necessary to have a good understanding of the material condition of the components at the time the assessment is made. Material conditions are determined from the review of maintenance history, such as inspection reports, test data, diagnostic data, craft feedback, spare parts use, operating records and a plant walkdown. From this an estimate can be rendered if the plant age is commensurate with its condition, that is, if its useful life has been expended faster than expected or the current condition is better than anticipated.

Aging Evaluation

Next is the aging evaluation to be performed for each major component or commodity group. Here the work performed by the industry groups and USNRC in support of the license renewal represents a basis to start the assessments. Typically a matrix is constructed, showing the basic component parts and materials, their applicable aging effects and associated aging mechanisms and the effective aging management programs. A typical aging matrix (this one for electric motors) is shown in Table 8.

For each line item, the plant's matching aging management program is identified and reviewed to determine if the effective attributes are included and to highlight any gaps that need to be addressed. The previous review of the operating history and plant condition records also contributes to this task to ascertain applicability and to assure that plant specific conditions are not overlooked.

Table 8: *Typical Aging Management Evaluation Matrix (Electric Motor)*

Structure or Components	Component/ Material Grouping	Plausible Aging Effects	Potential Aging Mechanisms	Present Plant Aging Management Programs
Rotor and Stator Windings End turns	Copper and Insulation	Discoloration, Burning, melting	Winding Shorts, Moisture Intrusion, Aging, Dirt, High Temperature	Motor Status Monitor. Refurbishment Consider internal inspection
		Overheating	Aging, Dirt	See above
Rotor Bars	Steel	Loose	Vibration, Age, Fatigue	Vibration monitoring On-line electrical tests
Rotor Shaft	Steel	Deformation, cracking	Vibration, fatigue, corrosion	Vibration monitoring Bearing temp. monitoring Internal visual inspection
Bearings	Various	Loss of Material, Cracking	Friction, Wear, Loss of lubrication	Vibration monitoring Temperature monitoring Oil sampling, analysis Thermography Internal inspection
Wiring, Terminations	Copper, Insulation	Loss of Contact, Cracking	Pinched, crimped, loose wire, Aging, corrosion	Thermography Visual inspection High pot tests
Frame, Base Plate	Carbon Steel	Loss of Material, Cracking, Deformation	Corrosion, Vibration, Loose Bolts	Vibration monitoring Visual inspections Recoating MR Structures Monitoring
Cooling Coils, Oil and water piping/reservoirs	Carbon Steel, SS	Leakage, Cracking	Corrosion, Wear, Vibration, Fatigue	Oil sampling, testing Visual inspection (E/I) Operator/SE rounds
Oil sight glass, Oil seals	Various non-metallic	Leakage	Corrosion, aging, wear, fatigue	Visual inspection Operator/SE rounds Periodic replacement
Sensors (RTDs, TCs, LVDTs, level, pressure, DP)	Various	Loss of signal, Drifting	Vibration, aging, corrosion	Calibration Replacement
Space heaters	Copper, insulation	Loss of continuity	Loose, broken wire, Moisture accumulation	Winding temp. monitoring Functional testing Thermostat calibration

Obsolescence Assessment

An obsolescence assessment provides a critical review of the potential technical obsolescence of the equipment. The industry is experiencing a serious exodus of original equipment vendors, many vendors do no longer support warranty and equipment services or have terminated production of spare parts. This puts the plant into a vulnerable position, leaving few of acceptable options, including re-engineering or reverse engineering, substituting newer models that often do not fit the original configuration envelope, upgrading technology (analog to digital) creating electronic-computer interface problems or scavenging parts from abandoned plants. The obsolescence assessment criteria and the relative ranking applied by a number of plants are shown on Table 9.

The first step is to assess the exposure level to obsolescence. Typically the electrical-electronic and instrumentation and control components are affected most prominently.

Obsolescence is ranked by applying a set of questions and ranking the applicability of each question. The total numerical value is compared to a traffic light scale to indicate the eminence of obsolescence. While this may not be a true scientific process, it nevertheless provides a timeframe for corrective or mitigative action.

The "traffic light" ranking for obsolescence is:

- Total Score is < 6.0, RED and the SSC obsolescence is serious. Potential options to deal with obsolescence and contingency planning should be identified. Guidance on the modeling, timing and costs of these contingencies and the associated risks should be provided.
- Total Score is between 6.0 and 10.0, YELLOW and the SSC may have longer-term concerns for obsolescence. Contingency planning and options should be considered.
- Total Score is > 10, GREEN and the SSC is not likely affected by obsolescence.

TABLE 9: *Technical Obsolescence Evaluation Criteria (Breakers)*

	Technical Obsolescence Evaluation Criteria	Base Score Yes=5 No=0	GE AKR	GE AM	W DHP	ABB K-line
1	Is the SSC still being manufactured and will it be available for at least the next five years?	5	0	0	0	5
2	Is there more than one supplier for the SSC for the foreseeable future?	3	0	0	0	0
3	Can the plant or outside suppliers manufacture the SSC in a reasonable time (within a refueling outage)?	3	0	0	0	3
4	Are there other sources or contingencies (from other plants, shared inventory, stock-piled parts, refurbishments, secondary suppliers, imitation parts, commercial dedications, etc) available in case of emergency?	3	3	3	3	3
5	Is the SSC frequency of failure/year times the number of the SSCs in the plant times the remaining operating life (in years) equal or lower than the number of stocked SSCs in the warehouse?	3	0	0	0	0
6	Can the spare part inventory be maintained for at least the next five years?	3	3	3	1	3
7	Is the SSC immune to significant aging degradation?	1	0	0	0	0
8	Can newer designs, technology, concepts be readily integrated with the existing configuration (hardware-software, digital-analog, solid-state, miniaturized electronics, smart components, etc)?	3	1.5	0	3	3
	Total Obsolescence Score	**24**	**7.5**	**6**	**7**	**17**

Determining LCM Planning Options and Plant Strategies

At this point in the LCM planning process, all the potential enhancements should be identified, such that a concise list of new or modified maintenance activities can be compiled, along with their costs and timing of implementation. Each goal can be met by a number of different options, called Alternatives in the LCM process. The Alternatives include:

- Maintain the Current Maintenance Program

  This is considered the base case against which other options are compared. The model assumes that current maintenance practices are continued and failure rates will gradually increase commensurate with progressive aging. Equipment replacement at time of failure is the planned corrective action.

- Optimize the PM Program

  Low cost PM activities are implemented on the basis of their cost effectiveness. Existing tasks are fine tuned or modified to be more effective and tasks with little payback are eliminated. A variant to the PM program is preventive replacement of components that have reached their predetermined useful life.

- Make Design Changes and Modifications

  Typically this option is a more costly alternative and makes sense for long-term operation if the design change avoids costly failures and lost power generation. There is a caution though in that design changes are often not proven concepts and may turn out worse for the plant.

- Designate Components as Run-to-failure

  For many unimportant components this is a reasonable alternative. In order to be effective, there must be a task that determines when failure has occurred so that a replacement can be installed.

Plant operating strategies need to be established, such that the LCM planning can consider the appropriate planning horizon, which is the remaining operating life, whether the plant is base loaded or cycled and if a power uprate is contemplated.

Economic Analysis of LCM Alternatives

The last step of the LCM process is to consolidate the technical data, failure data and financial/cost data to be loaded into financial analysis software, called LcmVALUE, to perform the Net Present Value (NPV) and Benefit to Investment Ratio (BIR) calculations that provide the measure of economic feasibility. The Alternative with the lowest NPV cost and the highest BIR is the preferred option. If the results are very close (i.e. within 1% of each other) additional sensitivity and uncertainty analysis are typically performed to render a confident recommendation. Results are highly dependant on long-term financial assumptions (such as discount rate, inflation rate, cost of power generation, cost of labor/materials, etc) and small changes cause large fluctuations in the results.

The Use of Probabilistic Risk Analysis for Maintenance

The probabilistic risk analysis (PRA) was initially developed for the safety related part of the nuclear power plant to facilitate simulation of various accident scenarios. Over time, plant-specific failure data became available and Bayesian updating brought about much more accurate modeling of the plant. With the promulgation of the Maintenance Rule, the PRA was expanded to now also include the power generation part of the plant, such that on-line risk modeling has become feasible and is performed on a routine basis. Outage times associated with preventive maintenance and surveillance testing as well as unanticipated equipment failures (emergent events) can be modeled and the risk impact associated with maintenance activities can be assessed on a continual basis. As plants continue to age, the increased equipment failures, if any, will be captured and the overall plant risk changes will have to be managed within the acceptance limits. This is another form of aging management trending at a higher level.

This PRA fidelity has led to new uses of the PRA, including risk ranking (RRW and RAW) of individual systems, evaluation of configuration and design changes prior to actual implementation and risk informed inspection plans (locations and frequency). Most recently, the USNRC has issued guidance for plant owners to apply PRA to fire protection and quality assurance programs.

Regulatory and Industry Aging Research

Early EPRI Pilot Plant and Demonstration Projects for License Renewal

As noted previously, the EPRI and DOE co-sponsored life extension pilot plant projects were initiated to study the feasibility and boundaries of nuclear plant life extension beyond the licensed 40-year life. With the new construction of power plants virtually coming to a halt after the 1979 Three Mile Island event, the electric generation industry and the US Department of Energy (DOE) were looking at long-term solutions to a looming energy crisis. Extending the plant life by some 20 years is equivalent of building 50 new power plants. The objectives of these early studies, as quoted in the Phase 1 BWR Pilot Plant Life Extension Report were:

> *To determine a realistic life goal for BWR plants, to identify major degradation mechanisms and potential technical obstacles to life extension, and to provide a methodology for BWR life extension programs*.

As the project was nearing completion and confidence in life extension was assured, economic obstacles and limits became an additional concern, as the list of potential new aging management activities and component replacements grew. The projects did develop the concept of "Critical Components" to delineate those that are essential to function and must be carefully managed to achieve the new life goals. It was also discovered that steel and concrete structures are not immune to aging and require aging management, largely through preventive techniques such as sealing, protective coatings and cathodic protection.

With the success of the pilot plants, a Phase 2 project was initiated to begin aging assessment of most of the plant components and commodity groups (cable, piping, structures, pressure boundary components, batteries, diesel generators, power generation equipment, etc). Among the top twelve critical components, all but two were passive components, the control center and diesel generators being the only active components. The Phase 2 report laid the foundation for identifying potential aging effects and mechanisms, their rate of degradation, manifestation of degradation and vulnerable locations. The studies also provided a first glance at potential aging management tactics from preventive/predictive maintenance, mitigation techniques, replacement options and repair feasibility.

The demonstration projects were initiated following the USNRC promulgation of the original License Renewal Rule in December 1991. The principal objective was to test the Rule's provisions and to generate the first license renewal application. It turned out not to be feasible and became unworkable in addition to plant owners concerns for an unstable licensing environment with open interpretation of the actual requirements. The license renewal application was never filed and the action prodded the NRC to revise and simplify the rule in 1995.

DOE-Sandia Aging Management Guides (AMG)

During the license renewal demonstration project phase, a need arose to study the critical components in more detail and to generate a generic AMG that could be used by other plants in their applications as well as be subjected to NRC review. The USDOE through the Sandia National Laboratory contracted for the development of ten individual AMGs, using a standard format and content guide. The ten critical components to be covered were chosen by an industry consortium and included the following reports:

- Electrical Switchgear (SAND93-7027)
- Pumps (SAND93-7045)
- Battery Chargers, Inverters & Uninterruptible Power Supplies (SAND93-7046)
- Power and Distribution Transformers (SAND93-7068)
- Motor Control Centers (SAND93-7069)
- Heat Exchangers (SAND93-7070)
- Stationary Batteries (SAND93-7071)
- Tanks and Pools (SAND96-0343)
- Electrical Cable and Terminations (SAND96-0344)
- Non-Reactor Pressure Boundary Piping (Draft) (TR-88953

While these reports cover both, passive (Heat Exchangers, Piping, Tanks/Pools, Cable) and active components (batteries, inverters/UPS, pumps, transformers, switchgear and motor control centers) they have become a valuable industry reference for the assessment of power production equipment. The AMGs contain a comprehensive review of industry operating experience, failure data, aging management techniques, and aging management options. The Cable AMG has become the industry bible on cable degradation, cable life determination and cable aging management.

EPRI Generic License Renewal Industry Reports for Major Components

In parallel to the DOE-Sandia AMGs EPRI also produced ten License Renewal Industry Reports. The EPRI addressed issues related to both the boiling water reactors (BWR) and the pressurized water reactors (PWR).

The EPRI reports were developed with participation from the General Electric BWR and Westinghouse PWR Owners Groups. The objectives of the EPRI reports were to provide the nuclear industry with aging technical basis documents and to support the technical review of license renewal applications by the USNRC.

The long-lived passive components and structures examined in the reports included:

- BWR plant primary containment
- PWR containment structures
- Class 1 structures
- PWR reactor coolant system
- low voltage, in-containment, environmentally-qualified cable

- BWR primary coolant pressure boundary
- BWR and PWR reactor vessels
- BWR and PWR reactor vessel internals

These reports are in-depth studies of historical performance and operating experience, failures and failure history, aging effects, and aging mechanism. The reports also provided information on aging management technologies and programs and discussed the aging management options for component parts and aging mechanisms that are not currently being managed or are not accessible (such as, underground structures, embedded steel and piping, and cable in conduits).

Over the years these reports have been of significant value for both the US nuclear industry and regulator as well as for nuclear plant operators and regulators in other countries. In particular, the reports on structures and containments have formed the basis of similar aging reports developed by the International Atomic Energy Agency in Vienna.

Much of the information in the reports on Class 1 structures and cables is application to both nuclear and non-nuclear facilities.

NRC Nuclear Plant Aging Research (NPAR) Program

To compensate for and to supplement the industry research of component aging, the USNRC funded a large multimillion-dollar research program to study aging of more than 100 different topics and components. Most of the actual research was conducted by the national laboratories (Oakridge, Argonne, Pacific Northwest, Sandia, and Idaho). The USNRC managed the program and provided for the technical review of selected reports by industry experts and users. A summary report (NUREG- 1377) was generated and updated annually to maintain an overview of the program status, components and topics being studied, short briefing reports and summaries for those reports completed. The reports for the selected components included passive and active components, as well as special topics, such as fatigue, material embrittlement, monitoring for aging, maintenance issues, seismic effects, and operating experience. Most of these reports are readily available from the NRC website. A more detailed discussion of the NPAR Program can be found in the companion briefing report *Condition Monitoring of Passive Systems, Structures, and Components* (CGI Report 06:22).

EPRI Generic Aging Management Tools

As a follow-up to the earlier industry reports for critical component aging, EPRI consolidated the research conducted within those reports, other owner’s group initiatives, the NRC NPAR program and the early LICENSE RENEWAL applications in a series of Aging Management Tools. The three documents provide specific guidance in matrix format (similar to the later GALL report) to license renewal applicants for the applicable aging effects, mechanisms, exposure environments, affected materials and effective aging management programs. The tools are as follows:

- *Mechanical Implementation Guideline And Mechanical Tools* – contains a number of individual reports to cover the applicable service conditions and environments for:
    - treated water conditions
    - raw water
    - oil containing systems
    - gas containing systems
    - external surfaces
    - bolting
    - heat exchangers
    - fatigue affected systems
- *License Renewal Electrical Handbook* – contains aging management guidance for electrical cable and terminations, penetrations, buses, conductors and insulators.
- *Aging Effects for Structures and Structural Components (Structural Tools)* -- contains aging management guidance for steel and concrete structures (beams, columns, floors, walls, foundations, roofs, etc), above and below grade, underwater, in freeze-thaw climate, indoors and outdoors. Also covered are piping and cable tray supports, electrical and control cabinets, racks and enclosures, fire barriers, elastomer seals and barriers, galvanized steel and threaded fasteners. An example of the aging matrix for steel components is shown on Table 10.

The INPO AP-913 Equipment Reliability Program

The Nuclear Plant Reliability Data Search (NPRDS) database was created by INPO following the Three Mile Island event to respond to NRC requests for generic operating experience accumulation and assessment. Each plant provided input of component failures and causes to facilitate searches and to identify precursors to potential failures. With the promulgation of the maintenance rule, a new software tool was required to manage the failures associated with the equipment included under the Maintenance Rule. These failures are considered “Maintenance Preventable Functional Failures” (MPFFs) and repeat failures and are reportable under the Maintenance Rule. In operation since 1996, the database now contains more than 100,000 failure events and descriptions and as such is a credible basis for establishing component failure rates. One major shortcoming is the absence of component populations, such that component estimates need to be made for the 104 operating plants. For some commodities, such as valves, breakers or cables, uncertainties are encountered. Nevertheless, the database has become a very useful tool to examine operating experience and failure modes. Another caution for the use of the data is the fact that reporting of failures is only required for systems and components included in the scope of the Maintenance Rule, that is largely safety related equipment.

Table 10: *Applicable Aging Effects for Structural Steel Components and Materials*

APPLICABLE AGING EFFECTS	CARBON STEEL	LOW-ALLOY STEEL	GALVANIZED STEEL	STAINLESS STEEL
Loss of Material				
General Corrosion	Y	Y	N-protected atmosphere/weather Y-exposed atmosphere/weather	N
Galvanic Corrosion	N	N	N	N
Crevice Corrosion	N	N	N	N
Pitting Corrosion	N	N	N	N
Erosion and Erosion Corrosion	NA	NA	NA	NA
Microbiologically Induced Corrosion	N	N	N	N
Wear	N	N	N	N
Cracking				
Hydrogen Damage	N	N	N	N
Stress Corrosion	N	N	N	N
Fatigue	N	N	N	N
Mechanical Distortion				
Creep	N	N	N	N
Fatigue	N	N	N	N
Change in Material Properties				
Elevated temperatures	N	N	N	N
Irradiation Embrittlement	N*	N*	N*	N*
Intermetallic Embrittlement	NA	NA	N-provided temperature < 400 °F	NA
Key: Y- aging mechanism is applicable . N- aging mechanism is not applicable NA- Not Applicable to this chapter *- Outside Primary Shield Wall.				

While not a bona fide research program, this INPO developed reliability management guide provides plant owners with a structured methodology to more effectively apply and manage their maintenance programs. The guide is not mandatory and plant owners can customize their programs to incorporate existing programs and procedures, as long as the principal objective of improving equipment reliability is met. The programmatic details are discussed in an earlier section of this report.

NEI Guidelines

The Nuclear Energy Institute (NEI) has accepted the responsibility of developing industry guidelines for the implementation of new regulatory requirements and other topics not addressed by EPRI or INPO, such as business planning. The three most prominent guides associated with aging management of plant systems, structures, and components are:

- NEI-95-10, *Industry Guidelines for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule Plants* – this guide is discussed in the License Renewal Rule section of this report and in the companion briefing report CGI 06:22
- NEI-93-01, *Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants* – this guide is discussed in the Maintenance Rule section of this report
- NEI-AP-940, *Nuclear Asset Management Process Description and Guideline*:

In NEI-AP-940 asset management process guidance includes strategic and generation planning, project evaluation and ranking, long range planning, budgeting, and plant / fleet valuation. The process deals with the high-level business management of a fleet or a single plant. The most interesting section of this guide is the topic of project evaluation and ranking. Industry surveys showed that there is no consensus with respect to the method of selecting and ranking specific projects from a multiple projects listing and being restrained by a fixed budget. Many different methods have been proposed, from risk ranking, expert panel (Delphi), cost-benefit, operational priorities, safety considerations and the rucksack method (what to take with you in a fixed volume rucksack for a one week survival trip).

Ongoing EPRI Aging Research

A lesson learned about aging management, is that no matter how precise and detailed the aging studies are performed, there is always the unexpected, often a combination of events that surprises the engineers. In the nuclear industry there is no exception and unknown material behavior, degradation mechanisms and aging effects are discovered as the plants age. Largely due to the inspection programs in place today, these “surprises” are discovered in time to facilitate timely corrective actions.

During the last ten years, accelerated degradation associated with crack initiation was discovered in the stainless steel reactor vessel internals. The cause was determined to be stress corrosion cracking, assisted by fatigue and un-annealed weldments. A major research project was initiated by the industry and managed by EPRI to find solutions, mitigation techniques and new inspection methods to investigate, size, and analyze the cracks. Just recently another new issue emerged concerning the cracking of Alloy 600 and similar Inconel alloys. This also is attributed to stress corrosion cracking, aggravated by the unique water environment (high hydrogen levels and borated water) in the PWR reactors. As before, the industry convened a large task force to deal with the issue and EPRI again is managing the project for the plant owners. These two projects and others are now combined under the EPRI Materials Research Program (MRP).

Code and Standards Perspective of Aging Management

In principle, Codes and Standards are voluntary, unless mandated by a government authority. The ASME Boiler and Pressure Vessel Code (ASME-BPVC) is mandated by the state authorities and the NRC for safety related pressure vessels, while the Electrical

Code (IEEE) and Fire Protection Codes are enforced by national building codes (NFPA). The American Concrete Institute Codes are mandated by the building codes for residential and commercial construction, however for power plants and other industrial facilities the Engineer/Designer is responsible for Code compliance. For the safety related portion of the nuclear plant, the USNRC mandates certain ACI Codes, including ACI-349. A brief description of the code activities involving aging management is presented below.

ASME-BPVC PLEX Working Group

Section XI, "Inservice Inspection of Nuclear Power Plant Components" of the ASME Boiler Code is the applicable Code specifying inspection and testing requirements for the nuclear plant components, as well as frequency of inspections, personnel qualifications and inspection techniques to be applied. A special working group was established within Section XI to accommodate the eventual integration of aging management into the Code. As a first action, the committee removed the 40-year inspection schedule (four 10-year cycles) from the Code to permit continued 10-year intervals until the plant shuts down for decommissioning. In the interim the Working Group monitors technical issues as they emerge from the license renewal process for future integration. The Code does not react to new issues very quickly and purposely takes its time to test implementation problems before codifying them.

IEEE Working Group for Aging Management of Electrical and I&C Equipment

The Institute of Electrical and Electronics Engineers (IEEE) generated a guide for aging management of electrical and instrumentation equipment, P-1205 (draft), "IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class IE Equipment Used in Nuclear Power Generating Stations". The guide contains a comprehensive aging effects and mechanisms matrix and the associated effective aging management methods. It is not certain if this guide was ever formally issued.

ACI Standards for Evaluation of Existing Concrete Structures

The American Concrete Institute (ACI) had a working condition survey standard for concrete inservice since 1968, ACI-201.1R, "Guide for Making a Condition Survey of Concrete Inservice". The Code addresses some 38 degradation effects, including ten types of cracking. For most of the degradation effects, reference photographs are provided for the inspector to discern the exact nature of the defects. The code has been updated a number of times, the 1996 version being the latest. The code has been widely in use for municipal and public use structures (garages, bridges, event buildings, etc), but has also been applied to power plants, including the nuclear facilities.

More recently, ACI issued a new Code with specific application to safety related structures, ACI-349-3R, "Evaluation of Existing Nuclear Safety Related Concrete Structures". In addition to the condition survey requirements as defined in ACI-201, this standard provides definitive acceptance criteria at two levels, Acceptance without further evaluation and acceptance with review. The acceptance criteria for concrete inspections are provided in Table 11.

Table 11: *Concrete Inspection Acceptance Criteria (from ACI-349), Edited*

Concrete Defect Description	Acceptance Criteria Without Review	Acceptance Criteria With Review
Leaching and Chemical Attack	None permitted	None permitted
Abrasion, Corrosion, Cavitation	None permitted	Evaluate Defects
Drummy Areas, Poor Concrete	None permitted	<Cover Concrete
Popouts, Voids	<20mm diameter or Equiv. Area	<50mm diameter or Equiv. Area
Scaling	<5mm in depth	<30mm in depth
Spalling	<10mm in depth, <100mm in any dimension	<20mm in depth, <200mm in any dimension
Passive Cracks	<04mm in width	<1.0mm in width
Passive Deflection, Settlement	None permitted	Within design limits
Loss of Coatings	$<4000mm^2$ for any area	$>4000mm^2$ for any area
Leakage	None permitted	Evaluate any leakage

Lessons Learned from the Initial License Renewals

The license renewal process has been a 25-year learning curve. The initial version of the Rule in 1991 was found to be open-ended with an overwhelming program scope. The nuclear industry and the USNRC staff identified many problems with the initial Rule. The amended Rule in 1995 established a regulatory process that is simpler, more stable, and more predictable than the initial License Renewal Rule. It put the focus of the license renewal assessment on the licensees aging management activities concerning passive and long-lived SSCs. It also clarified the focus on managing the adverse effects of aging rather than identification of all aging mechanisms. The changes to the integrated plant assessment (IPA) process were to make it simpler and more consistent with the revised focus on passive, long-lived systems, structures and components. However there remained a number of areas where further improvements were needed in the application process.

In the late 1990’s the Calvert Cliffs plant announced its plan to file an application using the revised Rule and the NEI license renewal application guide, NEI 95-10. NEI 95-10 provides an approach that the USNRC has found to be acceptable and has endorsed for implementing the requirements of the License Renewal Rule. The guidelines in the NEI 95-10 report are based on industry experience in implementing License Renewal Rule.

The review of the Calvert Cliffs applications by the USNRC staff revealed some serious problems. These included the fact the staff had very little guidance, no training, and a diverse view of what the regulations actually meant. Also, questions were raised with respect to the license renewal application costs, utility commitment, and effectiveness of the Rule. Senior management from both the USNRC and the nuclear industry worked to address these and other weaknesses with the license renewal process. This involved numerous site visits to familiarize the USNRC staff with site conditions and to conduct scope audits.

It became apparent that much of the information to be developed for an application is of a generic nature. It was determined that standards and guidance were needed to avoid unnecessary duplication of work. Guidance was also needed to avoid technical inconsistencies so that there are not different interpretations of the technical findings and conclusions from one application reviewer to another.

To address these and other issues the USNRC and the nuclear industry developed a number of guidance documents. One of the key documents has been the Generic Aging Lessons Learned (GALL) Report (NUREG-1801). The GALL report provides a template of aging management programs that have been determined to be acceptable by the USNRC to manage the aging effects of safety critical passive and long-lived SSCs. The GALL Report documents the USNRC’s basis for determining which existing programs are adequate without modification and which existing programs should be augmented for license renewal. A complimentary Standard Review Plan (NUREG-1800) was developed as a guide to the USNRC staff for their review of the application information.

Strong emphasis has been placed on training NRC staff and plant owners to assure that all stakeholders are aware of the process, requirements, tools and reference guides. The NRC implemented an extensive training program for their staff members and assigned additional inexperienced staff to their site audit teams to observe and learn the process. Training modules also were developed by the owners groups and EPRI to be conducted at the plant sites for different levels of staff, management briefings and working level indoctrinations.

The next license renewal applicants were able to use these guidance documents in the development of their applications. Major cost reductions were realized with the streamlined process. Savings were estimated to be in the range of 50% to 75% with respect to the Calvert Cliffs project costs. Further improvements were initiated by the USNRC to shorten the review process from three years to less than two years, to deal with staff shortages and reflect the learning curve. The nuclear industry and NEI also sponsored development of the Aging Management Tools, a commitment database (to assure that applicants do not over-commit or fail to address previous USNRC issues), and a searchable database for NRC generic communications.

The lessons learned from these efforts and the continued review process has been incorporated into the latest revision of the GALL report and the Standard Review Plan. The process has matured to a point were the USNRC has been able to review multiple plant applications in parallel. Utilities have seen major cost and schedule reductions for the license renewal process; fewer site visits and experienced significantly less interaction with the USNRC during the review process.

Some to the key documents that are used by both the licensees and the USNRC during the license renewal process are listed in Table 12. These are all “living documents”. Revised versions of the reports are routinely produced that incorporate changes based on experience gained from numerous license renewal application reviews by USNRC staff and from insights identified by the industry. For example, the, NEI 95-10 is currently in its sixth revision.

Table 12: *License Renewal Support and Guidance Documents*

Document Title	Document Identifier
Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants	NUREG-1800 (USNRC)
Generic Aging Lessons Learned (GALL) Report	NUREG-1801 (USNRC)
Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses	Regulatory Guide 1.188 (USNRC)
License Renewal Inspections	Inspection Manual 71002 (USNRC)
Policy and Guidance for License Renewal Inspection Programs	MC-2516 (USNRC)
Industry Guidelines for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule	NEI 95-10 (Nuclear Energy Institute)

Reaching Process Consensus among Stakeholders

As described above, the license renewal process has undergone substantial evolution. This implies recognition of the need to and willingness to change by all parties involved. Pressure was applied on the regulator to keep the process on track, simplify it and make it effective for all stakeholders. The mistakes made with the initial rule could not be repeated and a stable and workable process had become essential for success. Such a proven process also lends itself to standardization, further assuring consistency and efficiency. One of the key concerns with new regulations is the threat of “Rule Creep”, that is the ever-changing interpretations of the regulations, issuance of new guidance, raising of new issues, different treatment of the same issue for other applicants and the constant desire to invent new wheels. In this case, the NRC and utilities were jointly motivated to develop a streamlined and stable methodology. The development of the GALL report and NEI license renewal Guide, NEI 95-10, are considered major tools to achieve those objectives.

The process has by no means found its end point, additional lessons learned, improvements and experience feedback are being monitored and revisions of the key references are planned to capture process changes. The most recent evidence of the continuing consensus evolution is an EPRI project to prepare so-called “Road Maps” for generic technical issues and associated aging management programs. This project evolved from the tallying and review of individual plant commitments and to sort those that are common to many plants and therefore deserve identical treatment and resolution. These road maps are to assist plant owners to develop implementation tasks for their license renewal commitments at least costs and assuring acceptability of implementation. The road maps also identify technical issues that are not fully resolved yet and require research to facilitate task implementation prior to the start of the license renewal period. The NRC is expected to audit these implementation activities in the future and they are tracking compliance with the applicant’s commitments.

Another method to communicate current development, lessons learned and ideas of process improvement is facilitated through frequent workshops sponsored by the NRC and the industry. These workshops encourage presentations from all stakeholders and the public to solicit input and opinions. They are also a vehicle to share information with management, vendors, suppliers of services, inspectors, public members and other interested parties. All or most of the license renewal information, including the complete application packages, USNRC application reviews (SER), rules and regulations and guidance documents (GALL, SRP-LR, NEI-95-10, Regulatory Guides, Interim Staff Guidance) are available on the USNRC website (www.nrc.gov).

Life Extension Implementation at the Plants

The Two-Step Process

Life Extension for a plant is considered a two-step process. The initial step is to secure regulatory approval through license renewal application process. The second step is to actually implement life extension for the plant. Although the approval of a license renewal allows continued operation for 20-years it does not require such operation. The decision to actually operate beyond the current license period is up to the licensee. It is dependent on such factors as power generation planning, economic justification, and prevailing condition of the plant.

The aging management requirements of the license renewal application only apply to the safety-related scope under the License Renewal Rule – about one-third of the plant equipment. In order to prepare the plant for life extension, the remaining power production part of the plant has to be upgraded and evaluated to assure that the equipment can support reliable operation for an extra 20 years. Many plants will wait until about five years before the extended license becomes effective (at year 35 of the plant life) to avoid large capital investments that may become stranded if the plant owners decide not to implement life extension. Often these objectives are compromised, because the plant may need a new turbine generator or main transformer at year 34, without life extension such an investment would not be cost beneficial such that the extended life period is needed in the cost benefit analysis.

Proactive Implementation Tasks

While most of the license renewal commitments for the plant apply only for the extended operating period, there are a number of preparatory and mitigative actions taken by the plants to reduce future costs and to collect the information needed for future assessments. The following are some of the proactive, diagnostic, preventive, predictive and investigative activities performed by plants in preparation for license renewal:

- Temperature Survey of Spaces for EQ
    - Initial survey with Pyrometer or Thermography to locate “Hot Spots”, actual temperature variations within the space, room or enclosure, locations with temporary elevated temperature and containing vulnerable electrical equipment
- Fatigue Cycle Counting and Monitoring
    - Simple cycle counting and transient categorization to be compared to the design basis assumptions and projected for 60 years. Thermal transient monitoring to determine the rate of transients for future reclassification and margin hunting.
- Biological Essays (Tests) of Water Sources
    - Sampling and testing for MIC of all water sources (Service Water, raw water, demineralized water, closed loops, sumps, storage tanks, lube oil, fuel oil)

- Visual Inspection of Inaccessible Areas
    - When opening up equipment (pumps, valves, heat exchangers, tanks/vessels) or removing insulation, perform a visual (VT-1 or VT-3) inspection of the normally inaccessible surfaces and record the conditions (corrosion, cracking, loss of material, staining, etc). When excavating buried/embedded pipe, steel and concrete structures, trenches, cable ducts, perform a VT-1 or VT-3 and take good pictures of the normally inaccessible surfaces.
- Wall Thickness Measurements
    - When possible, conduct sample UT wall thickness measurements on carbon steel piping, valve bodies, pump casings, heat exchanger and vessel shells, tank walls and bottoms, etc. Identify and record abnormal conditions.
- Underwater Inspections
    - When using divers in the intake, fuel pools, etc, train divers for VT-1 examinations and debrief afterwards. Document conditions and take photos if possible.
- Soil and Groundwater Tests
    - Take soil and groundwater samples and test for chlorides, sulfates, silica, cement paste, iron oxides. Take samples as near to the structure as possible from test wells, borings, and excavations. Monitor groundwater level and variations at least over a few years.
- Settlement Monitoring
    - If the plant sits on soil or piles, consider installing, reactivating or updating the settlement monitoring system for the principal structures (Containment, Auxiliary or Reactor Building, Intake).
- Air Sampling and Testing
    - Sample and test the external plant air to determine the extent and type of air pollution at the site, measure chlorides, CO, SOX, NOX, particulates to establish aggressiveness. For ocean plants, measure the concentration of NaCl (salt) for various weather and wind conditions in the ventilation intakes.
- Beltline Material Surveillance
    - Review the material test coupon withdrawal schedule and make adjustments as early as possible to accommodate a 60-year (and possibly 80 year) operating period. Consider reinsertion of the material, using miniaturization and reconstitution of the coupons for future embrittlement tests.

License Renewal Commitment Implementation after Year 40

Once the plant approaches the end of the current operating license and decided that economics dictate continuation of operation and that an extended life is warranted and desirable, the commitments made in the license renewal application become mandatory and full implementation must be achieved before the plant can continue to operate past

40 years. Plants consider it unwise to wait to the last minute, particularly for new inspection programs, such as certain one-time inspections, where surprises could occur in that unexpected degradation is found. In such case, the aging management program for the affected components would not be effective and would require changes and regulatory review prior to continued operation. Other programs that merely require procedure changes or administrative actions could be delayed to the last year. Another aspect of the implementation process is to consider the generic guidance developed by NEI and EPRI, such as the “Road Maps” discussed earlier. It is important to implement tasks that are acceptable to the regulator, feature the attributes and requirements as well as scope committed to in the application.

Typically a plant will have between 200 and 400 individual license renewal tasks to implement. To assure that the tasks are all properly scheduled for completion and documentation is generated, a computerized database is normally used to track responsibility, schedule, completion status and associated design and quality assurance records/references. Many tasks require follow-up actions or re-inspections at a predetermined interval and inspection results must be evaluated and documented. The plant has to be able to verify implementation to the regulator’s onsite inspectors.

A new Appendix to the License Renewal Guide, NEI 95-10, has been drafted and issued. The purpose of this Appendix is to provide guidance to utility personnel for the follow-up actions after receipt of a renewed license.

In parallel, the USNRC has also developed inspection guidance for their onsite inspectors, as well as training programs to get ready for the extended operating period. The applicable inspection program policy document is embodied in the USNRC’s “Policy and Guidance for License Renewal Inspection Programs”, MC-2516. Because of its relevance an edited copy of this policy document has been included in Appendix E.

International Applications and Interaction

The US has taken an active role in transferring the aging management and life extension technology to other countries and international organizations. This has taken place at all levels, starting with the NRC participation in IAEA working groups to draft international standards, to individual consultants assisting foreign countries and organizations to develop their own programs. Many international conferences on nuclear technology, such as ICONE, SMIRTand IPLEX, have carried specific sessions to address life extension, aging management and operational issues. US corporations and government agencies have extensively participated in these sessions and shared their experiences and processes with the international community. Additionally, the USNRC website provides most of the regulatory guidance documents and licensing proceedings without restrictions. The following specific examples of technology transfer provide just a small piece of the word wide application of this US technology.

- The Spanish regulator required the Spanish utilities to implement the Maintenance Rule as defined in the US regulations. Assistance was provided to the utilities in shaping a program tailored to their needs and unique circumstances. Spanish regulatory representatives cross trained with the USNRC in their Washington headquarters to learn about the implementation process and the procedures.
- The IAEA relied on US participation to draft License Renewal and Aging Management standards, using US precedents, methodology and references. This has led to the development of international policy documents and generation of a number of Aging Management Standards (Containment, Reactor Vessel)
- Japan having some of the oldest nuclear plants in the world, has benefited from the early aging studies conducted in the US. Aging analysis reports have been made available to Japanese utilities through a number of technology exchange channels.
- South Korea has applied US life extension technology to their plants, both in the aging evaluations and degradation assessments/inspections.
- France (EDF) through a technology exchange agreement with EPRI has acquired the US life extension technology and life cycle management processes. A number of training seminars and workshops were held in France to present the technology.
- Switzerland, through their utility owners group, has made use of the life extension and aging management technology, specifically the identification of applicable aging effects and mechanisms and their aging management programs. Following a successful national referendum on the continuation of nuclear power, the Swiss plants are preparing their license renewal applications.

Lessons Learned – Possible Petroleum Industry Application

For over fifteen years the USNRC and the nuclear industry have been continuously refining both the license renewal requirements and the renewal process. There are many aspects of these aging management and life extension efforts and the lessons that have been learned that can be of potential value to the PSA and the Norwegian petroleum industry.

Aging Research Information

The wealth of aging related information produced by the NPAR and industry aging research programs remains a useful resource for both nuclear and non-nuclear organizations. Although the aging studies examined SSCs with respect to their operation in the nuclear plants, much of the aging degradation and aging management information is applicable to the petroleum and other industrial sectors.

Continuous Improvement

Over the years both the USNRC and the industry have been working to make the license renewal requirements and the renewal process more efficient and effective. For example, the initial version of the Rule did not provide a predictable nor stable process – it was too open ended with too broad a scope. It was determined that many aging effects were already adequately addressed during the initial operating license period. Also, the initial Rule did not allow sufficient credit for existing programs, particularly those under the USNRC Maintenance Rule, which help manage plant aging phenomena as part of the on-going maintenance program tasks.

The resulting revised Rule established a simpler, more stable, and more predictable regulatory process. The key changes that were made included:

- focusing on the adverse effects of aging rather than identification of all aging mechanisms – identification of individual aging mechanisms is not required
- simplifying the integrated plant assessment process and madding it consistent with the revised focus on the detrimental effects of aging
- adding an evaluation of time-limited aging analyses (TLAA)
- requiring only passive, long-lived structures and components to be subject to an aging management review for license renewal – removing active SSCs from license renewal

Passive versus Active SSCs

An important aspect of the US nuclear plant life extension requirements is the distinction between passive and active systems, structures, and components. Passive SSCs are those that do not move to function (such as, structures, heat exchangers, cables, valve and pump bodies, and piping). Their age related degradation can only be monitored and trended by performing periodic condition assessments (such as inspections, testing, and measurements).

By focusing the license renewal process on safety critical passive and long-lived components the process has been reduced to a manageable proportions – licensees are not required to consider all SSCs in order to justify extended operations.

Guidance and Training

One of the key lessons has been the need to provide clear guidance and support to all involved parties. Both the USNRC and the industry have developed guidance documents to assist in the development of aging management programs, the preparation of the renewal application, and the review of the application. As lessons are learned these guidance documents are revised to capture new insights or address emerging issues. Along with the guidance documents, training programs and support activities have greatly reduced the time and expense in preparing, reviewing, and approving the license renewal applications. The training must be supplemented with guides, pilot studies, working examples, and procedures to assure consistency of application.

Integration of Aging Management Program Requirements

From the description of the many diverse aging management programs it becomes clear that plants have a difficult time to integrate all the different requirements and to avoid duplication and non-effective maintenance tasks. Too much maintenance can lead to reliability and availability concerns and it is necessary to strive for an adequate balance. Other drivers are manpower, costs, prioritization of activities and consolidation of tasks. As part of the Maintenance Rule, the plants already have established a 13-week schedule, that is each system or train (where systems have redundant trains) will be taken out of service for one week every 13 weeks, or four times a year. During this one-week system outage, all the preventive and corrective maintenance tasks are to be completed, including invasive inspections, tests, calibrations, repairs and replacements. Once license renewal activities begin, additional tasks will have to be squeezed into the maintenance week, likely at the expense of other similar tasks.

Long-term Maintenance Strategy

When contemplating aging management for a facility, the useful life expectancy and associated planning horizon must be established first, to provide a basis for the long-term maintenance strategy. The ultimate operating life has a profound impact on the selection of appropriate and economic maintenance alternatives. It is prudent to link asset management to maintenance strategy with an objective to preserve the assets as long as economically feasible. A lesson learned from the aging management projects is that most components can be replaced and that good aging management can preserve structures for decades if not centuries (the B-52 aircraft are over 50 years old and are still flying).

Reducing Component Failures

No other maintenance action taken in the plant will have as much impact on equipment reliability and plant availability as reducing the failure rates of components. The plant or system performance cannot be better than the worst performing critical component. All efforts must therefore be directed to identify incipient failures, precursors and age related degradation. This implies that inspections and diagnostics must be employed in areas where failure knowledge and prediction is inadequate. In general plants are not aggressive enough to reduce failures and to invest in predictive maintenance. Even though some plants have a “Zero Failure Tolerance” policy, when it comes to making investments, replacements are preferred.

Effectiveness of Condition Monitoring

It is not unusual to find that plants have implemented predictive maintenance tools to monitor equipment conditions, but the diagnostics are not effective in preventing failures. One example is vibration monitoring of rotating equipment, when data is read infrequently (once a month) with portable equipment. Bearing degradation can progress, and often will, from minor imbalance to catastrophic failure within minutes or hours. Continuous monitoring with alert and warning levels is significantly more effective. Another example is oil analysis and ferrography performed at certain intervals is mostly used to justify an increase in the oil change interval. Installing oil reservoir breather caps and filters will be more effective to keep contaminants out of the oil. Thermography has slowly made inroads in detecting degradation and incipient failures, even though the surveys are done typically only annually and only for readily accessible equipment. More aggressive and effective thermography can be performed for electrical equipment inside enclosures, using infrared windows. Enclosed motors also can be surveyed internally using infrared windows on the casing to measure rotor and stator, slip ring and bearing temperatures to identify hot spots.

Establishing Appropriate Inspection Procedures

The two major questions concerning an effective inspection program are: What and how often to inspect? For components such as cable, piping, valves, pumps, motors a sampling program is the most effective means of inspection. Sampling rates must be representative with respect to component size, vendor, materials, service and environmental exposure. An example is to start with a 10% sampling rate and decreasing the rate after five years if nothing is found. Or doubling the rate if defective equipment is found. If more than one deficiency is found, a 100% inspection would be justified.

If a risk analysis is available, component selection and prioritization can be made by using risk measures. If aging evaluations have been performed, the most vulnerable components and locations should be known and become the focus of inspections.
The frequency of inspections depends on the degradation one is looking for. If the known degradation is a fairly rapid and aggressive process, inspection periods of one to two years are not uncommon, while inspections of steel and concrete structures are undertaken at ten-year intervals. If acceptable defects are found or if repairs have been performed, the inspection periods should be shortened, commensurate with the rate of degradation or on an annual basis.

Just because nothing has been found for 20 or 30 years does not imply that degradation is absent, it may just be slow or takes a long time to crack initiation and propagation. The most troubling degradation issues in the nuclear plants became apparent after more 20 years of operation and exposure.

Aging Management of Inaccessible Equipment

A major concern in the license renewal process is equipment that is not readily accessible to inspection, testing or diagnostics. Underground piping and cable, embedded steel, underwater structures are examples of these cases. Unique programs were developed to deal with these components and to assure that degradation is adequately managed. Onetime inspections, selected excavations, use of test coupons and monitoring of the service environment (soil and water chemistry, evidence of corrosion products) were employed to indicate when and where degradation becomes active. Managing these inaccessible components and structures should be a priority, because replacement and repair is not usually a feasible option.

Sharing Experiences

An effective failure reduction strategy is to access, review and analyze equipment failures at other facilities. Problems and difficulties at older facilities or those that have greater operating hours can be a valuable source of leading indicators of what to watch out for. Generic failures may point out particularly vulnerable parts, impact of abnormal operation, failure indicators, methods of detection and actual service hours to failure.

Another important source of information is gained by monitoring of other plant's experience and programs to identify those activities that work and those that do not work. The sharing of best practices, however has been impeded by the deregulation of the nuclear power industry. Unfortunately, in certain cases, information that provides an economic advantage to one plant becomes a valuable commodity that is likely not to be shared with others.

Manufactures usually do not have a good understanding of the operational performance of their equipment in the field and are only performing root cause assessments when they receive a warranty claim. Maintenance recommendations from the manufacturer must be taken with great caution and only if a technical basis exists for their recommendations, such as operational failure rate trends and component life expectancies.

Pilot Projects

When attempting to create new regulations with complex processes, it is imperative to test the regulations and processes in a real application environment. The first License Renewal rule failed as a result of applying it to a demonstration project. All stakeholders must participate in this test program to understand the implications and be willing to search for acceptable compromise. The revised rule was a success because of frequent interaction among the stakeholders, participation of and guidance from senior management representatives and a willingness to change and adapt during the development process.

Properly Quantify Consequential Failure Costs

Often when cost benefit analyses are performed to justify corrective or preventive actions following equipment failures, the consequential failure costs are not adequately incorporate into the analyses. This can lead to erroneous assumptions and conclusions.

Failure costs can include lost production, personnel injury, lost work time, and medical costs. The more serious the failure the greater the impact on the plant and the organization. Some plants have been forced to shutdown for several years because of equipment failures and human errors. It is therefore important to identify and quantify the consequential failure costs to support reliable conclusions and to justify implementation of a predictive maintenance and effective aging management strategy

Quantify Consequential Failure Costs

Often when cost benefit analyses are performed to justify corrective or preventive actions following equipment failures, the consequential failure costs are not adequately incorporate into the analyses. This can lead to erroneous assumptions and conclusions. As stated earlier, the value of one day's lost power production approaches one Million Dollars for most plants. In addition, some failures cause personnel injury, lost work time, medical costs and inquiries by the safety authorities. Other failure consequences may even be more drastic, including fires, flooding, steam escape, explosions, radioactive contamination or releases. The more serious the failure, the more impact there will be on the corporate well being, from an impact on the stock price, annual dividend and earnings, public image and potential regulatory actions and fines. Some plants have been forced to shutdown for periods up to two years, because of equipment failures and human errors. It is therefore important to identify and quantify the consequential failure costs to support reliable conclusions and to justify implementation of a predictive maintenance and effective aging management strategy.

Conclusions

The aging management and life extension process for the US nuclear industry has been refined and improved over the years. It has become an efficient and effective method to ensure that the nuclear plants in the United States can be safely operated beyond their original 40-year operating license. By dividing the safety critical systems, structures, and components into passive and active categories the industry and regulator have reduced the potentially overwhelming analysis effort to a reasonable and manageable size.

By working together, the nuclear industry and the US Nuclear Regulatory Commission (USNRC) have been able to technically justify life extension. The process has been structured to not be an economic or resource burden on either the licensees or the USNRC. However, all parties are continually reviewing the process and results to identify where improvements can be made.

The process has been selected as a viable method by many international regulatory and nuclear industry organizations, including those in Spain, Taiwan, and Korea. The International Atomic Energy Agency in Vienna has also adopted the process as the model for ensuring safe extended life operations.

The aging management and life extension process can be easily adapted to other industries. The development strategy, research material, specific elements of the process, and many of the lessons learned can all be of potential value to the PSA and Norwegian petroleum industry in ensuring safe extended operations of the facilities.

Appendices

A The Maintenance Rule: Title 10 of the US Code of Federal Regulations, Part 50.65 (10 CFR 54.65)

B The License Renewal Rule: Title 10 of the US Code of Federal Regulations, Part 54 (10 CFR Part 54)

C USNRC Guidance Concerning Aging Effects and Aging Mechanisms

D Aging Management Program Example – Concrete Structures Monitoring: GALL Report-(NUREG-1801 Vol 2)

E License Renewal Inspection Policy and Guidance: USNRC Inspection Manual Chapter (MC) 2516 – Policy and Guidance for the License Renewal Inspection Programs

F Nuclear Related Aging Management and Life Extension Abbreviations and Acronyms

G Bibliography of Selected Nuclear Aging Management and Life Extension Reports

Appendix A

The Maintenance Rule

Title 10 of the US Code of Federal Regulations, Part 50.65
(10 CFR 54.65)

Requirements for Monitoring the Effectiveness of
Maintenance at Nuclear Power Plants

The requirements of this section are applicable during all conditions of plant operation, including normal shutdown operations.

(a)(1) Each holder of a license to operate a nuclear power plant under Secs. 50.21(b) or 50.22 shall monitor the performance or condition of structures, systems, or components, against licensee-established goals, in a manner sufficient to provide reasonable assurance that such structures, systems, and components, as defined in paragraph (b), are capable of fulfilling their intended functions. Such goals shall be established commensurate with safety and, where practical, take into account industry-wide operating experience. When the performance or condition of a structure, system, or component does not meet established goals, appropriate corrective action shall be taken. For a nuclear power plant for which the licensee has submitted the certifications specified in Sec. 50.82(a)(1), this section only shall apply to the extent that the licensee shall monitor the performance or condition of all structures, systems, or components associated with the storage, control, and maintenance of spent fuel in a safe condition, in a manner sufficient to provide reasonable assurance that such structures, systems, and components are capable of fulfilling their intended functions.

(2) Monitoring as specified in paragraph (a)(1) of this section is not required where it has been demonstrated that the performance or condition of a structure, system, or component is being effectively controlled through the performance of appropriate preventive maintenance, such that the structure, system, or component remains capable of performing its intended function.

(3) Performance and condition monitoring activities and associated goals and preventive maintenance activities shall be evaluated at least every refueling cycle provided the interval between evaluations does not exceed 24 months. The evaluations shall take into account, where practical, industry-wide operating experience. Adjustments shall be made where necessary to ensure that the objective of preventing failures of structures, systems, and components through maintenance is appropriately balanced against the objective of minimizing unavailability of structures, systems, and components due to monitoring or preventive maintenance.

(4) Before performing maintenance activities (including but not limited to surveillance, post-maintenance testing, and corrective and preventive maintenance), the licensee shall assess and manage the increase in risk that may result from the proposed maintenance activities. The scope of the assessment may be limited to structures, systems, and components that a risk-informed evaluation process has shown to be significant to public health and safety.

(b) The scope of the monitoring program specified in paragraph (a)(1) of this section shall include safety related and nonsafety related structures, systems, and components, as follows:

(1) Safety-related structures, systems and components that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, or the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the guidelines in Sec. 50.34(a)(1), Sec. 50.67(b)(2), or Sec. 100.11 of this chapter, as applicable.

(2) Nonsafety related structures, systems, or components:

(i) That are relied upon to mitigate accidents or transients or are used in plant emergency operating procedures (EOPs); or

(ii) Whose failure could prevent safety-related structures, systems, and components from fulfilling their safety-related function; or

(iii) Whose failure could cause a reactor scram or actuation of a safety-related system.

(c) The requirements of this section shall be implemented by each licensee no later than July 10, 1996.

Appendix B

The License Renewal Rule

Title 10 of the US Code of Federal Regulations, Part 54
(10 CFR Part 54)

Requirements for Renewal of Operating Licenses for Nuclear Power Plants

General Provisions

§ 54.1 Purpose.

This part governs the issuance of renewed operating licenses for nuclear power plants licensed pursuant to Sections 103 or 104b of the Atomic Energy Act of 1954, as amended (68 Stat. 919), and Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242).

§ 54.3 Definitions.

(a) As used in this part,

Current licensing basis (CLB) is the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The CLB includes the NRC regulations contained in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications. It also includes the plant-specific design-basis information defined in 10 CFR 50.2 as documented in the most recent final safety analysis report (FSAR) as required by 10 CFR 50.71 and the licensee's commitments remaining in effect that were made in docketed licensing correspondence such as licensee responses to NRC bulletins, generic letters, and enforcement actions, as well as licensee commitments documented in NRC safety evaluations or licensee event reports.

Integrated plant assessment (IPA) is a licensee assessment that demonstrates that a nuclear power plant facility's structures and components requiring aging management review in accordance with § 54.21(a) for license renewal have been identified and 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.

Nuclear power plant means a nuclear power facility of a type described in 10 CFR 50.21(b) or 50.22.

Time-limited aging analyses, for the purposes of this part, are those licensee calculations and analyses that:

(1) Involve systems, structures, and components within the scope of license renewal, as delineated in § 54.4(a);
(2) consider the effects of aging;
(3) Involve time-limited assumptions defined by the current operating term, for example, 40 years;
(4) Were determined to be relevant by the licensee in making a safety determination;
(5) Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, and component to perform its intended functions, as delineated in § 54.4(b); and

(6) Are contained or incorporated by reference in the CLB.

(b) All other terms in this part have the same meanings as set out in 10 CFR 50.2 or Section 11 of the Atomic Energy Act, as applicable.

§ 54.4 Scope.

(a) Plant systems, structures, and components within the scope of this part are--

(1) Safety-related systems, structures, and components which are those relied upon to remain functional during and following design-basis events (as defined in 10 CFR 50.49 (b)(1)) to ensure the following functions--

(i) The integrity of the reactor coolant pressure boundary;

(ii) The capability to shut down the reactor and maintain it in a safe shutdown condition; or

(iii) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to those referred to in § 50.34(a)(1), § 50.67(b)(2), or § 100.11 of this chapter, as applicable.

(2) All nonsafety-related systems, structures, and components whose failure could prevent satisfactory accomplishment of any of the functions identified in paragraphs (a)(1)(i), (ii), or (iii) of this section.

(3) All systems, structures, and components relied on in safety analyses or plant evaluations to perform a function that demonstrates compliance with the Commission's regulations for fire protection (10 CFR 50.48), environmental qualification (10 CFR 50.49), pressurized thermal shock (10 CFR 50.61), anticipated transients without scram (10 CFR 50.62), and station blackout (10 CFR 50.63).

(b) The intended functions that these systems, structures, and components must be shown to fulfill in § 54.21 are those functions that are the bases for including them within the scope of license renewal as specified in paragraphs (a)(1) - (3) of this section.

[60 FR 22491, May 8, 1995, as amended at 61 FR 65175, Dec. 11, 1996; 64 FR 72002, Dec. 23, 1999]

§ 54.5 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 54.7 written communications.

All applications, correspondence, reports, and other written communications shall be filed in accordance with applicable portions of 10 CFR 50.4.

§ 54.9 Information collection requirements: OMB approval.

(a) The Nuclear Regulatory Commission has submitted the information collection requirements contained in this part to the Office of Management and Budget (OMB) for approval as required by the Paperwork Reduction Act (44 U.S.C. 3501 et seq.). The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. OMB has approved the information collection requirements contained in this part under control number 3150-0155.

(b) The approved information requirements contained in this part appear in §§ 54.13, 54.15, 54.17, 54.19, 54.21, 54.22, 54.23, 54.33, and 54.37.

[60 FR 22491, May 8, 1995, as amended at 62 FR 52188, Oct. 6, 1997; 67 FR 67100, Nov. 4, 2002]

§ 54.11 Public inspection of applications.

Applications and documents submitted to the Commission in connection with renewal applications may be made available for public inspection in accordance with the provisions of the regulations contained in 10 CFR Part 2.

§ 54.13 Completeness and accuracy of information.

(a) Information provided to the Commission by an applicant for a renewed license or information required by statute or by the Commission's regulations, orders, or license conditions to be maintained by the applicant must be complete and accurate in all material respects.

(b) Each applicant shall notify the Commission of information identified by the applicant as having, for the regulated activity, a significant implication for public health and safety or common defense and security. An applicant violates this paragraph only if the applicant fails to notify the Commission of information that the applicant has identified as having a significant implication for public health and safety or common defense and security. Notification must be provided to the Administrator of the appropriate regional office within 2 working days of identifying the information. This requirement is not applicable to information that is already required to be provided to the Commission by other reporting or updating requirements.

§ 54.15 Specific exemptions.

Exemptions from the requirements of this part may be granted by the Commission in accordance with 10 CFR 50.12.

§ 54.17 Filing of application.

(a) The filing of an application for a renewed license must be in accordance with Subpart A of 10 CFR Part 2 and 10 CFR 50.4 and 50.30.
(b) Any person who is a citizen, national, or agent of a foreign country, or any corporation, or other entity which the Commission knows or has reason to know is owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government, is ineligible to apply for and obtain a renewed license.
(c) An application for a renewed license may not be submitted to the Commission earlier than 20 years before the expiration of the operating license currently in effect.
(d) An applicant may combine an application for a renewed license with applications for other kinds of licenses.
(e) An application may incorporate by reference information contained in previous applications for licenses or license amendments, statements, correspondence, or reports filed with the Commission, provided that the references are clear and specific.
(f) If the application contains Restricted Data or other defense information, it must be prepared in such a manner that all Restricted Data and other defense information are separated from unclassified information in accordance with 10 CFR 50.33(j).
(g) As part of its application, and in any event before the receipt of Restricted Data or classified National Security Information or the issuance of a renewed license, the applicant shall agree in writing that it will not permit any individual to have access to or any facility to possess Restricted Data or classified National Security Information until the individual and/or facility has been approved for such access under the provisions of 10 CFR Parts 25 and/or 95. The agreement of the applicant in this regard shall be deemed part of the renewed license, whether so stated therein or not.
[60 FR 22491, May 8, 1995, as amended at 62 FR 17690, Apr. 11, 1997]

§ 54.19 Contents of application--general information.

(a) Each application must provide the information specified in 10 CFR 50.33(a) through (e), (h), and (i). Alternatively, the application may incorporate by reference other documents that provide the information required by this section.
(b) Each application must include conforming changes to the standard indemnity agreement, 10 CFR 140.92, Appendix B, to account for the expiration term of the proposed renewed license.

§ 54.21 Contents of application--technical information.

Each application must contain the following information:
(a) An integrated plant assessment (IPA). The IPA must--

- (1) For those systems, structures, and components within the scope of this part, as delineated in § 54.4, identify and list those structures and components subject to an aging management review. Structures and components subject to an aging management review shall encompass those structures and components--
  - (i) That perform an intended function, as described in § 54.4, without moving parts or without a change in configuration or properties. These structures and components include, but are not limited to, the reactor vessel, the reactor coolant system pressure boundary, steam generators, the pressurizer, piping, pump casings, valve bodies, the core shroud, component supports, pressure retaining boundaries, heat exchangers, ventilation ducts, the containment, the containment liner, electrical and mechanical penetrations, equipment hatches, seismic Category I structures, electrical cables and connections, cable trays, and electrical cabinets, excluding, but not limited to, pumps (except casing), valves (except body), motors, diesel generators, air compressors, snubbers, the control rod drive, ventilation dampers, pressure transmitters, pressure indicators, water level indicators, switchgears, cooling fans, transistors, batteries, breakers, relays, switches, power inverters, circuit boards, battery chargers, and power supplies; and
  - (ii) That are not subject to replacement based on a qualified life or specified time period.
- (2) Describe and justify the methods used in paragraph (a)(1) of this section.
- (3) For each structure and component identified in paragraph (a)(1) of this section, demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB for the period of extended operation.

(b) CLB changes during NRC review of the application. Each year following submittal of the license renewal application and at least 3 months before scheduled completion of the NRC review, an amendment to the renewal application must be submitted that identifies any change to the CLB of the facility that materially affects the contents of the license renewal application, including the FSAR supplement.
(c) An evaluation of time-limited aging analyses.

(1) A list of time-limited aging analyses, as defined in § 54.3, must be provided. The applicant shall demonstrate that--

(i) The analyses remain valid for the period of extended operation;

(ii) The analyses have been projected to the end of the period of extended operation; or

(iii) The effects of aging on the intended function(s) will be adequately managed for the period of extended operation.

(2) A list must be provided of plant-specific exemptions granted pursuant to 10 CFR 50.12 and in effect that are based on time-limited aging analyses as defined in § 54.3. The applicant shall provide an evaluation that justifies the continuation of these exemptions for the period of extended operation.

(d) An FSAR supplement. The FSAR supplement for the facility must contain a summary description of the programs and activities for managing the effects of aging and the evaluation of time-limited aging analyses for the period of extended operation determined by paragraphs (a) and (c) of this section, respectively.

§ 54.22 Contents of application--technical specifications.

Each application must include any technical specification changes or additions necessary to manage the effects of aging during the period of extended operation as part of the renewal application. The justification for changes or additions to the technical specifications must be contained in the license renewal application.

§ 54.23 Contents of application--environmental information.

Each application must include a supplement to the environmental report that complies with the requirements of Subpart A of 10 CFR Part 51.

§ 54.25 Report of the Advisory Committee on Reactor Safeguards.

Each renewal application will be referred to the Advisory Committee on Reactor Safeguards for a review and report. Any report will be made part of the record of the application and made available to the public, except to the extent that security classification prevents disclosure.

§ 54.27 Hearings.

A notice of an opportunity for a hearing will be published in the Federal Register in accordance with 10 CFR 2.105. In the absence of a request for a hearing filed within 30 days by a person whose interest may be affected, the Commission may issue a renewed operating license without a hearing upon 30-day notice and publication once in the *Federal Register* of its intent to do so.

§ 54.29 Standards for issuance of a renewed license.

A renewed license may be issued by the Commission up to the full term authorized by § 54.31 if the Commission finds that:

(a) Actions have been identified and have been or will be taken with respect to the matters identified in Paragraphs (a)(1) and (a)(2) of this section, such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB, and that any changes made to the plant's CLB in order to comply with this paragraph are in accord with the Act and the Commission's regulations. These matters are:

(1) managing the effects of aging during the period of extended operation on the functionality of structures and components that have been identified to require review under § 54.21(a)(1); and

(2) time-limited aging analyses that have been identified to require review under § 54.21(c).

(b) Any applicable requirements of Subpart A of 10 CFR Part 51 have been satisfied.

(c) Any matters raised under § 2.335 have been addressed.

[69 FR 2279, Jan. 14, 2004]

§ 54.30 Matters not subject to a renewal review.

(a) If the reviews required by § 54.21 (a) or (c) show that there is not reasonable assurance during the current license term that licensed activities will be conducted in accordance with the CLB, then the licensee shall take measures under its current license, as appropriate, to ensure that the intended function of those systems, structures or components will be maintained in accordance with the CLB throughout the term of its current license.

(b) The licensee's compliance with the obligation under Paragraph (a) of this section to take measures under its current license is not within the scope of the license renewal review.

§ 54.31 Issuance of a renewed license.

(a) A renewed license will be of the class for which the operating license currently in effect was issued.

(b) A renewed license will be issued for a fixed period of time, which is the sum of the additional amount of time beyond the expiration of the operating license (not to exceed 20 years) that is requested in a renewal application plus the remaining number of years on the operating license currently in effect. The term of any renewed license may not exceed 40 years.

(c) A renewed license will become effective immediately upon its issuance, thereby superseding the operating license previously in effect. If a renewed license is subsequently set aside upon further administrative or judicial appeal, the operating license previously in effect will be reinstated unless its term has expired and the renewal application was not filed in a timely manner.
(d) A renewed license may be subsequently renewed in accordance with all applicable requirements.

§ 54.33 Continuation of CLB and conditions of renewed license.

(a) Whether stated therein or not, each renewed license will contain and otherwise be subject to the conditions set forth in 10 CFR 50.54.
(b) Each renewed license will be issued in such form and contain such conditions and limitations, including technical specifications, as the Commission deems appropriate and necessary to help ensure that systems, structures, and components subject to review in accordance with § 54.21 will continue to perform their intended functions for the period of extended operation. In addition, the renewed license will be issued in such form and contain such conditions and limitations as the Commission deems appropriate and necessary to help ensure that systems, structures, and components associated with any time-limited aging analyses will continue to perform their intended functions for the period of extended operation.
(c) Each renewed license will include those conditions to protect the environment that were imposed pursuant to 10 CFR 50.36b and that are part of the CLB for the facility at the time of issuance of the renewed license. These conditions may be supplemented or amended as necessary to protect the environment during the term of the renewed license and will be derived from information contained in the supplement to the environmental report submitted pursuant to 10 CFR Part 51, as analyzed and evaluated in the NRC record of decision. The conditions will identify the obligations of the licensee in the environmental area, including, as appropriate, requirements for reporting and recordkeeping of environmental data and any conditions and monitoring requirements for the protection of the nonaquatic environment.
(d) The licensing basis for the renewed license includes the CLB, as defined in § 54.3(a); the inclusion in the licensing basis of matters such as licensee commitments does not change the legal status of those matters unless specifically so ordered pursuant to paragraphs (b) or (c) of this section.

§ 54.35 Requirements during term of renewed license.

During the term of a renewed license, licensees shall be subject to and shall continue to comply with all Commission regulations contained in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, and 100, and the appendices to these parts that are applicable to holders of operating licenses.

§ 54.37 Additional records and recordkeeping requirements.

(a) The licensee shall retain in an auditable and retrievable form for the term of the renewed operating license all information and documentation required by, or otherwise necessary to document compliance with, the provisions of this part.
(b) After the renewed license is issued, the FSAR update required by 10 CFR 50.71(e) must include any systems, structures, and components newly identified that would have been subject to an aging management review or evaluation of time-limited aging analyses in accordance with § 54.21. This FSAR update must describe how the effects of aging will be managed such that the intended function(s) in § 54.4(b) will be effectively maintained during the period of extended operation.

§ 54.41 Violations.

(a) The Commission may obtain an injunction or other court order to prevent a violation of the provisions of the following acts--
- (1) The Atomic Energy Act of 1954, as amended.
- (2) Title II of the Energy Reorganization Act of 1974, as amended or
- (3) A regulation or order issued pursuant to those acts.

(b) The Commission may obtain a court order for the payment of a civil penalty imposed under Section 234 of the Atomic Energy Act--
- (1) For violations of the following--
  - (i) Sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Atomic Energy Act of 1954, as amended;
  - (ii) Section 206 of the Energy Reorganization Act;
  - (iii) Any rule, regulation, or order issued pursuant to the sections specified in paragraph (b)(1)(i) of this section;
  - (iv) Any term, condition, or limitation of any license issued under the sections specified in paragraph (b)(1)(i) of this section.

(2) For any violation for which a license may be revoked under Section 186 of the Atomic Energy Act of 1954, as amended.

Appendix C

USNRC Guidance Concerning Aging Effects & Aging Mechanisms

Table C-1: *Aging Effects* (Source: GALL Report - NUREG-1801)

Selected Definitions & Use of Terms for Describing and Standardizing Aging Effects	
Changes in dimensions	Changes in dimensions can result from void swelling.
Concrete cracking and spalling	Concrete cracking and spalling can result from freeze-thaw, aggressive chemical attack, and reaction with aggregates.
Crack growth	Increase in crack size, attributable to cyclic loading.
Cracking	This term is used in this document to be synonymous with the phrase "crack initiation and growth" in metallic substrates. Cracking in concrete can be caused by restraint shrinkage, creep, and aggressive environment.
Cracking, loss of bond, and loss of material (spalling, scaling)	Cracking, loss of bond, and loss of material (spalling, scaling) can be caused by corrosion of embedded steel in concrete.
Cracks; distortion; increase in component stress level	Within concrete structures, cracks, distortion, and increase in component stress level can be caused by settlement. Although settlement can be occur in a soil environment, the symptoms can be manifested in either an air-indoor uncontrolled or air-outdoor environment.
Cumulative fatigue damage	Cumulative fatigue damage is due to fatigue, as defined by ASME Boiler and Pressure Vessel Code.
Degradation of insulator quality	The decrease in insulating capacity can result from the presence of salt deposits or surface contamination. Although this derives from an aging mechanism (presence of salt deposits or surface contamination) that may be due to temporary, transient environmental conditions, the net result may be long lasting and cumulative.
Embrittlement, cracking, melting, discoloration, swelling, or loss of dielectric strength leading to reduced insulation resistance; electrical failure	Embrittlement, cracking, melting, discoloration, swelling, or loss of dielectric strength leading to reduced insulation resistance, electrical failure can result from mechanisms such as thermal or thermoxidative degradation of organics; radiation-induced oxidation, radiolysis and photolysis (UV sensitive materials only) of organics; moisture intrusion; and ohmic heating.
Expansion and cracking	Within concrete structures, expansion and cracking can result from reaction with aggregates.
Fatigue	Fatigue in copper fuse holder clamps can result from ohmic heating, thermal cycling, electrical transients, frequent manipulation, vibration, chemical contamination, corrosion, oxidation.
Fretting or lockup	Fretting is an aging effect due to accelerated deterioration at the interface between contacting surfaces as the result of corrosion and slight oscillatory movement between the two surfaces. In essence, both fretting and lockup are due to mechanical wear.
Hardening and loss of strength	Hardening and loss of strength can result from Eastover degradation of seals and other elastomeric components. Elastomers can experience increased hardness, shrinkage, and loss of strength, due to weathering.
Increase in porosity and permeability, cracking, loss of material (spalling, scaling), loss of strength	Concrete can increase in porosity and permeability, cracking, loss of material (spalling, scaling) due to aggressive chemical attack. In concrete, loss of material (spalling, scaling) and cracking can result from freeze-thaw processes. Loss of strength can result from leaching of calcium hydroxide in the concrete.
Increased resistance of connection	Increased resistance of connection in electrical transmission conductors and connections can be caused by oxidation or loss of preload.
Ligament cracking	Steel tube support plates can experience ligament cracking due to corrosion.
Localized damage and breakdown of insulation leading to electrical failure	Localized damage in polymeric electrical conductor insulation leading to electrical failure can be due to a number of aging mechanisms including moisture intrusion, and the formation of water trees. Based on operating experience, localized damage

Selected Definitions & Use of Terms for Describing and Standardizing Aging Effects	
	and breakdown of insulation may be exacerbated by manufacturing defects in the insulation of older electrical conductors, external damage, or damage due to poor installation practices.
Loosening of bolted connections	The loosening of bolted bus duct connections due to thermal cycling can result from ohmic heating.
Loss of fracture toughness	Loss of fracture toughness can result from various aging mechanisms including thermal aging, thermal aging embrittlement, and neutron irradiation embrittlement.
Loss of leak tightness	Steel airlocks can experience loss of leak tightness in closed position resulting from mechanical wear of locks, hinges, and closure mechanisms.
Loss of material	Loss of material may be due to general corrosion, boric acid corrosion, pitting corrosion, galvanic corrosion, crevice corrosion, erosion, fretting, flow-accelerated corrosion, MIC, fouling, selective leaching, wastage, wear, and aggressive chemical attack. In concrete structures, loss of material can also be caused by abrasion or cavitation or corrosion of embedded steel. For high voltage insulators, loss of material can be attributed to mechanical wear or wind-induced abrasion and fatigue due to wind blowing on transmission conductors.
Loss of material, loss of form	In earthen water-control structures, the loss of material and loss of form can result from erosion, settlement, sedimentation, frost action, waves, currents, surface runoff, and seepage.
Loss of preload	Loss of preload due to gasket creep, thermal effects (including differential expansion and creep or stress relaxation), and self-loosening (which includes vibration, joint flexing, cyclic shear loads, thermal cycles) is an aging effect/mechanism accepted by industry as being within the scope of license renewal.
Loss of prestress	Loss of prestress in structural steel anchorage components can result from relaxation, shrinkage, creep, or elevated temperatures.
Reduction in foundation strength, cracking, differential settlement	Reduction in foundation strength, cracking, and differential settlement can result from erosion of porous concrete subfoundation.
Reduction of heat transfer	Reduction of heat transfer from fouling by the buildup, from whatever source, on the heat transfer surface. Although in heat exchangers, the tubes are the primary heat transfer component, heat exchanger internals including tubesheets and fins contribute to heat transfer and may be affected by the reduction of heat transfer due to fouling.
Reduction of strength and modulus	In concrete, reduction of strength and modulus can be attributed to elevated temperatures (>150°F general; >200°F local).
Reduction or loss of isolation function	Reduction or loss of isolation function in polymeric vibration isolation elements can result from elastomers exposed to radiation hardening, temperature, humidity, sustained vibratory loading.
Wall thinning	This is the term used to describe the specific type of loss of material due to flow-accelerated corrosion.

Table C-2: *Aging Mechanisms* (Source: GALL Report - NUREG-1801)

Selected Definitions & Use of Terms for Describing and Standardizing Aging Mechanisms	
Term	**Aging Mechanism Definition as used in the GALL Report**
Abrasion	As water migrates over a concrete surface, it may transport material that can abrade the concrete. The passage of water may also create a negative pressure at the water/air to concrete interface that can result in abrasion and cavitation degradation of the concrete. This may result in pitting or aggregate exposure due to loss of cement paste.
Aggressive chemical attack	Concrete, being highly alkaline (pH >12.5) is degraded by strong acids. Chlorides and sulfates of potassium, sodium, and magnesium may attack concrete, depending concentration in soil/ground water. Exposed surfaces of structures may be subject to sulfur-based acid-rain degradation. Minimum degradation thresholds are 500 ppm chlorides and 1500 ppm sulfates.
Boric acid corrosion	Corrosion by boric acid, which can occur where there is borated water leakage in an environment described as air with borated water leakage. See also Corrosion.
Cavitation	Formation and instantaneous collapse of innumerable tiny voids or cavities within a liquid subjected to rapid and intense pressure changes. Cavitation caused by severe turbulent flow can potentially lead to cavitation damage.
Chemical contamination	Degradation due to presence of chemical constituents.
Corrosion	Chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.
Corrosion of embedded steel	If pH of the concrete in which steel is embedded is reduced (pH < 11.5) by intrusion of aggressive ions (e.g., chlorides > 500 ppm) in the presence of oxygen, embedded steel corrosion may occur. A reduction in pH may be caused by the leaching of alkaline products through cracks, entry of acidic materials, or carbonation. Chlorides may also be present in the constituents of the original concrete mix. The severity of the corrosion is affected by the properties and types of cement, aggregates, and moisture content.
Creep	Creep, for a metallic material, refers to a time-dependent continuous deformation process under constant stress. It is an elevated temperature process and is not a concern for low alloy steel below 700°F, for austenitic alloys below 1000°F, and for Ni-based alloys below 1800°F. Creep, in concrete, is related to the loss of absorbed water from the hydrated cement paste. It is a function of modulus of elasticity of the aggregate. It may result in loss of prestress in the tendons used in prestressed concrete containment.
Crevice Corrosion	Localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment, because of close proximity between the metal and the surface of another material. Crevice corrosion occurs in a wetted or buried environment when a crevice or area of stagnant or low flow exists that allows a corrosive environment to develop in a component. It occurs most frequently in joints and connections, or points of contact between metals and non-metals, such as gasket surfaces, lap joints, and under bolt heads. Carbon steel, cast iron, low alloy steels, stainless steel, copper, and nickel base alloys are all susceptible to crevice corrosion. Steel can be subject to crevice corrosion in some cases after lining/cladding degradation.
Cyclic loading	One source of cyclic loading is due to periodic application of pressure loads and forces due to thermal movement of piping transmitted through penetrations and structures to which penetrations are connected. The typical result of cyclic loads on metal components is fatigue cracking and failure; however, the cyclic loads may also cause deformation that results in functional failure.
Deterioration of seals, gaskets, and moisture barriers (caulking, flashing, and other sealants)	Seals, gaskets, and moisture barriers (caulking, flashing, and other sealants) are subject to loss of sealing and leakage through containment caused by aging
Distortion	The aging mechanism of distortion can be caused by time dependent strain, or gradual elastic and plastic deformation of metal that is under constant stress at a value lower than its normal yield strength.
Elastomer degradation	Elastomer materials are substances whose elastic properties are similar to that of natural rubber. The term elastomer is sometimes used to technically distinguish synthetic rubbers and rubber-like plastics from natural rubber. Degradation may include cracking, crazing, fatigue breakdown, abrasion, chemical attacks, and weathering. [20, 21] Elastomer hardening refers to the degradation in elastic properties of the elastomer.

Selected Definitions & Use of Terms for Describing and Standardizing Aging Mechanisms	
Term	**Aging Mechanism Definition as used in the GALL Report**
Electrical transients	An electrical transient is a stressor caused by a voltage spike that can contribute to aging degradation. Certain types of high-energy electrical transients can contribute to electromechanical forces ultimately resulting in fatigue or loosening of bolted connections. Transient voltage surges are a major contributor to the early failure of sensitive electrical components
Elevated temperature	In concrete, reduction of strength and modulus can be attributed to elevated temperatures (>150°F general; >200°F local).
Erosion	Progressive loss of material from a solid surface due to mechanical interaction between that surface and a fluid, a multi-component fluid, or solid particles carried with the fluid.
Erosion settlement	Erosion (as defined above). Settlement of containment structure may occur during the design life due to changes in the site conditions, e.g., due to erosion or changes in the water table. The amount of settlement depends on the foundation material, and is generally determined by survey. Another term is erosion of the porous concrete sub-foundation.
Erosion, settlement, sedimentation, frost action, waves, currents, surface runoff, seepage	In earthen water-control structures, the loss of material and loss of form can result from erosion, settlement, sedimentation, frost action, waves, currents, surface Run-off, and seepage.
Fatigue	A phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, and grow under the action of the fluctuating stress. Fatigue due to vibratory and cyclic thermal loads is defined as the structural degradation that can occur as a result of repeated stress/strain cycles caused by fluctuating loads, e.g., from vibratory loads, and temperatures, giving rise to thermal loads. After repeated cyclic loading of sufficient magnitude, micro-structural damage may accumulate, leading to macroscopic crack initiation at the most vulnerable regions. Subsequent mechanical or thermal cyclic loading may lead to growth of the initiated crack. Vibration may result in component cyclic fatigue, as well as in cutting, wear, and abrasion, if left unabated. Vibration is generally induced by external equipment operation. It may also result from flow resonance or movement of pumps or valves in fluid systems. Crack initiation and growth resistance is governed by factors including stress range, mean stress, loading frequency, surface condition, and the presence of deleterious chemical species.
Flow-accelerated corrosion (FAC)	Also termed erosion-corrosion. A co-joint activity involving corrosion and erosion in the presence of a moving corrosive fluid, leading to the accelerated loss of material.
Fouling	An accumulation of deposits. This term includes accumulation and growth of aquatic organisms on a submerged metal surface and also includes the accumulation of deposits, usually inorganic, on heat exchanger tubing. Biofouling, as a subset of fouling, can be caused by either macro-organisms (such as barnacles, Asian clams, zebra mussels, and others found in fresh and salt water) or micro-organisms, e.g., algae. Fouling can also be categorized as particulate fouling (sediment, silt, dust, and corrosion products), marine biofouling, or macrofouling, e.g., peeled coatings, debris, etc. Fouling in a raw water system can occur on the piping, valves, and heat exchangers. Fouling can result in a reduction of heat transfer, loss of material, or a reduction in the system flow rate (this last aging effect is considered active and thus is not in the purview of license renewal).
Freeze-Thaw, frost action	Repeated freezing and thawing is known to be capable of causing severe degradation to the concrete characterized by scaling, cracking, and spalling. The cause of this phenomenon is water freezing within the pores of the concrete, creating hydraulic pressure that, if unrelieved, will lead to freeze-thaw degradation. Factors that enhance the resistance of concrete to freeze-thaw degradation are a) adequate air content (e.g., within ranges specified in ACI 301-84), b) low permeability, c) protection until adequate strength has developed, and d) surface coating applied to frequently wet-dry surfaces.
Fretting	Aging effect due to accelerated deterioration at the interface between contacting surfaces as the result of corrosion, and slight oscillatory movement between the two surfaces.
Galvanic corrosion	Accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte. Also called bimetallic corrosion, contact corrosion, dissimilar metal corrosion, or two-metal corrosion. Galvanic corrosion is an applicable aging mechanism for steel materials coupled to more noble metals in heat exchangers; galvanic corrosion of copper is of concern when coupled with the nobler stainless

Selected Definitions & Use of Terms for Describing and Standardizing Aging Mechanisms	
Term	**Aging Mechanism Definition as used in the GALL Report**
	steel.
General corrosion	Also known as uniform corrosion, corrosion proceeds at approximately the same rate over a metal surface. Loss of material due to general corrosion is an aging effect requiring management for low alloy steel, carbon steel, and cast iron in outdoor environments.
Intergranular stress corrosion cracking (IGSCC)	SCC in which the cracking occurs along grain boundaries.
Leaching of calcium hydroxide	Water passing through cracks, inadequately prepared construction joints, or areas that are not sufficiently consolidated during placing may dissolve some calcium containing products, of which calcium hydroxide is the most-readily soluble, in concrete. Once the calcium hydroxide has been leached away, other cementatious constituents become vulnerable to chemical decomposition, finally leaving only the silica and alumina gels behind with little strength. The water's aggressiveness in the leaching of calcium hydroxide depends on its salt content and temperature. This leaching action is effective only if the water passes through the concrete.
Mechanical loading	Applied loads of mechanical origins rather than from other sources, such as thermal.
Microbiologically influenced corrosion (MIC)	Any of the various forms of corrosion influenced by the presence and activities of such microorganisms as bacteria, fungi, and algae, and/or the products produced in their metabolism. Degradation of material that is accelerated due to conditions under a biofilm or microfouling tubercle, for example, anaerobic bacteria that can set up an electrochemical galvanic reaction or inactivate a passive protective film, or acid-producing bacterial that might produce corrosive metabolites.
Moisture intrusion	Influx of moisture through any viable process.
Ohmic heating	Ohmic heating is induced by current flow through a conductor and can be calculated using first principles of electricity and heat transfer. Ohmic heating is a thermal stressor and can be induced in situations, such as conductors passing through electrical penetrations. Ohmic heating is especially significant for power circuit penetrations.
Overload	Overload is one of the aging mechanisms that can cause loss of mechanical function in piping and components, such as constant and variable load spring hangers, guides, stops, sliding surfaces, design clearances, vibration isolators, fabricated from steel or other materials, such as Lubrite
Oxidation	Two types of reactions a) reaction in which there is an increase in valence resulting from a loss of electrons, or b) a corrosion reaction in which the corroded metal forms an oxide.
Photolysis	Chemical reactions induced or assisted by light.
Pitting corrosion	Localized corrosion of a metal surface, confined to a point or small area, which takes the form of cavities called pits.
Plastic deformation	Time-dependent strain, or gradual elastic and plastic deformation, of metal that is under constant stress at a value lower than its normal yield strength.
Presence of any salt deposits	The surface contamination resulting from the aggressive environment associated with the presence of any salt deposits can be an aging mechanism causing the aging effect of degradation of insulator quality. Although this aging mechanism may be due to temporary, transient environmental conditions, the net result may be long-lasting and cumulative for plants located in the vicinity of saltwater bodies.
Radiolysis	Chemical reactions induced or assisted by radiation. Radiolysis and photolysis aging mechanisms can occur in UV-sensitive organic materials.
Reaction with aggregate	The presence of reactive alkalis in concrete, can lead to subsequent reactions with aggregates that may be present. These alkalis are introduced mainly by cement, but also may come from admixtures, salt-contamination, seawater penetration, or solutions of deicing salts. These reactions include alkali-silica reactions, cement-aggregate reactions, and aggregate-carbonate reactions. These reactions may lead to expansion and cracking.
Restraint shrinkage	Restraint shrinkage can cause cracking in concrete transverse to the longitudinal construction joint.
Selective leaching	Also known as dealloying, e.g., dezincification or graphitic corrosion. Selective corrosion of one or more components of a solid solution alloy.
Settlement	Settlement of structures may occur during the design life due to changes in the site conditions, e.g., the water table. The amount of settlement depends on the foundation material and is

Selected Definitions & Use of Terms for Describing and Standardizing Aging Mechanisms	
Term	**Aging Mechanism Definition as used in the GALL Report**
	generally determined by survey.
Stress corrosion cracking (SCC)	Cracking of a metal produced by the combined action of corrosion and tensile stress (applied or residual).
Stress relaxation	Many of the bolts in reactor internals are stressed to a cold initial preload. When subject to high operating temperatures, over time, these bolts may loosen and the preload may be lost. Radiation can also cause stress relaxation, in highly stressed members such as bolts. Relaxation in structural steel anchorage components can be an aging mechanism contributing to the aging effect of loss of prestress.
Thermal aging embrittlement	Also termed thermal aging or thermal embrittlement. At operating temperatures of 500 to 650°F, cast austenitic stainless steels (CASS) exhibit a spinoidal decomposition of the ferrite phase into ferrite-rich and chromium-rich phases. This may give rise to significant embrittlement, i.e., reduction in fracture toughness, depending on the amount, morphology, and distribution of the ferrite phase and the composition of the steel. Thermal aging of materials other than CASS is a time- and temperature-dependent degradation mechanism that decreases material toughness. It includes temper embrittlement and strain aging embrittlement. Ferritic and low alloy steels are subject to both of these embrittlement, but wrought stainless steel is not affected by either of the processes.
Thermal effects, gasket creep, and self-loosening	Loss of preload due to gasket creep, thermal effects (including differential expansion and creep or stress relaxation), and self-loosening (which includes vibration, joint flexing, cyclic shear loads, thermal cycles) is within the scope of license renewal.
Thermal and mechanical loading	Loads (stress) due to mechanical or thermal (temperature) sources.
Thermal fatigue	Thermal (temperature) fatigue can result from phenomena such as thermal loading, thermal cycling, where there is cycling of the thermal loads and thermal stratification. Thermal stratification is a thermohydraulic condition with definitive hot and cold water boundary inducing thermal fatigue of the piping. Turbulent penetration is a thermo-hydraulic condition where hot and cold water mix as a result of turbulent flow conditions, leading to thermal fatigue of the piping.
Water trees	Water trees occur when the insulating materials are exposed to long-term, continuous electrical stress and moisture; these trees eventually result in breakdown of the dielectric and ultimate failure. The growth and propagation of water trees is somewhat unpredictable. Water treeing is a degradation and long-term failure phenomenon.
Wear	Wear is defined as the removal of surface layers due to relative motion between two surfaces or under the influence of hard abrasive particles. Wear occurs in parts that experience intermittent relative motion, frequent manipulation, or in clamped joints where relative motion is not intended but may occur due to a loss of the clamping force.
Weathering	Degradation of external surfaces of materials when exposed to outside environment.

Appendix D

Aging Management Program Example – Concrete Structures Monitoring

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XI.S2 ASME SECTION XI, SUBSECTION IWL

Program Description

10 CFR 50.55a imposes the examination requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, Subsection IWL for reinforced and prestressed concrete containments (Class CC). The scope of IWL includes reinforced concrete and unbonded post-tensioning systems. This evaluation covers both the 1992 edition with the 2001 edition[1] including the 2002 and 2003 Addenda, as approved in 10 CFR 50.55a. ASME Code Section XI, Subsection IWL and the additional requirements specified in 10 CFR 50.55a(b)(2) constitute an existing mandated program applicable to managing aging of containment reinforced concrete and unbonded post-tensioning systems for license renewal.

The primary inspection method specified in IWL is visual examination (VT-3C, VT-1, VT-1C). For prestressed containments, tendon wires are tested for yield strength, ultimate tensile strength, and elongation. Tendon corrosion protection medium is analyzed for alkalinity, water content, and soluble ion concentrations. Prestressing forces are measured in selected sample tendons. IWL specifies acceptance criteria, corrective actions, and expansion of the inspection scope when degradation exceeding the acceptance criteria is found.

The evaluation of 10 CFR 50.55a and Subsection IWL as an aging management program (AMP) for license renewal is provided below.

Evaluation and Technical Basis

1. *Scope of Program:* Subsection IWL-1000 specifies the components of concrete containments within its scope. The components within the scope of Subsection IWL are reinforced concrete and unbonded post-tensioning systems of Class CC containments, as defined by CC-1000. Subsection IWL exempts from examination portions of the concrete containment that are inaccessible (e.g., concrete covered by liner, foundation material, or backfill, or obstructed by adjacent structures or other components).

   10 CFR 50.55a(b)(2)(viii) specifies additional requirements for inaccessible areas. It states that the licensee is to evaluate the acceptability of concrete in inaccessible areas when conditions exist in accessible areas that could indicate the presence of or result in degradation to such inaccessible areas. Steel liners for concrete containments and their integral attachments are not within the scope of Subsection IWL, but are included within the scope of Subsection IWE.

2. *Preventive Action:* No preventive actions are specified; Subsection IWL is a monitoring program. If a coating program is currently credited for managing the effects of aging of concrete surfaces, then the program is to be continued during the period of extended operation.

3. *Parameters Monitored or Inspected:* Table IWL-2500-1 specifies two categories for examination of concrete surfaces: Category L-A for all concrete surfaces and Category L-

[1] An applicant may rely on a different version of the ASME Code, but should justify such use. An applicant may wish to refer to the SOC for an update of 10 CFR § 50.55a to justify use of a more recent edition of the Code.

B for concrete surfaces surrounding tendon anchorages. Both of these categories rely on visual examination methods. Concrete surfaces are examined for evidence of damage or degradation, such as concrete cracks. IWL-2510 specifies that concrete surfaces are examined for conditions indicative of degradation, such as those defined in ACI 201.1R-77. Table IWL-2500-1 also specifies Category L-B for test and examination requirements for unbonded post tensioning systems. Tendon anchorage and wires or strands are visually examined for cracks, corrosion, and mechanical damage. Tendon wires or strands are also tested for yield strength, ultimate tensile strength, and elongation. Tendon corrosion protection medium is tested by analysis for alkalinity, water content, and soluble ion concentrations.

4. ***Detection of Aging Effects:*** The frequency and scope of examinations specified in 10 CFR 50.55a and Subsection IWL ensure that aging effects would be detected before they would compromise the design-basis requirements. The frequency of inspection is specified in IWL-2400. Concrete inspections are performed in accordance with Examination Category L-A. Under Subsection IWL, inservice inspections for concrete and unbonded post-tensioning systems are required at one, three, and five years following the structural integrity test. Thereafter, inspections are performed at five-year intervals. For sites with two plants, the schedule for inservice inspection is provided in IWL-2421. In the case of tendons, only a sample of the tendons of each tendon type requires examination at each inspection. The tendons to be examined during an inspection are selected on a random basis. Table IWL-2521-1 specifies the number of tendons to be selected for each type (e.g., hoop, vertical, dome, helical, and inverted U) for each inspection period. The minimum number of each tendon type selected for inspection varies from 2 to 4%. Regarding detection methods for aging effects, all concrete surfaces receive a visual VT-3C examination. Selected areas, such as those that indicate suspect conditions and areas surrounding tendon anchorages, receive a more rigorous VT-1 or VT-1C examination. Prestressing forces in sample tendons are measured. In addition, one sample tendon of each type is detensioned. A single wire or strand is removed from each detensioned tendon for examination and testing. These visual examination methods and testing would identify the aging effects of accessible concrete components and prestressing systems in concrete containments.

5. ***Monitoring and Trending:*** Except in inaccessible areas, all concrete surfaces are monitored on a regular basis by virtue of the examination requirements. For prestressed containments, trending of prestressing forces in tendons is required in accordance with paragraph (b)(2)(viii) of 10 CFR 50.55a. In addition to the random sampling used for tendon examination, one tendon of each type is selected from the first-year inspection sample and designated as a common tendon. Each common tendon is then examined during each inspection. This procedure provides monitoring and trending information over the life of the plant. 10 CFR 50.55a and Subsection IWL also require that prestressing forces in all inspection sample tendons be measured by lift-off tests and compared with acceptance standards based on the predicted force for that type of tendon over its life.

6. ***Acceptance Criteria:*** IWL-3000 provides acceptance criteria for concrete containments. For concrete surfaces, the acceptance criteria rely on the determination of the "Responsible Engineer" (as defined by the ASME Code) regarding whether there is any evidence of damage or degradation sufficient to warrant further evaluation or repair. The acceptance criteria are qualitative; guidance is provided in IWL-2510, which references ACI 201.1R-77 for identification of concrete degradation. IWL-2320 requires that the Responsible Engineer be a registered professional engineer experienced in evaluating

the inservice condition of structural concrete and knowledgeable of the design and construction codes and other criteria used in design and construction of concrete containments. Quantitative acceptance criteria based on the "Evaluation Criteria" provided in Chapter 5 of ACI 349.3R may also be used to augment the qualitative assessment of the responsible engineer. The acceptance standards for the unbonded post-tensioning system are quantitative in nature. For the post-tensioning system, quantitative acceptance criteria are given for tendon force and elongation, tendon wire or strand samples, and corrosion protection medium. 10 CFR 50.55a and Subsection IWL do not define the method for calculating predicted tendon prestressing forces for comparison to the measured tendon lift-off forces. The predicted tendon forces are to be calculated in accordance with Regulatory Guide 1.35.1, which provides an acceptable methodology for use through the period of extended operation.

7. ***Corrective Actions:*** Subsection IWL specifies that items for which examination results do not meet the acceptance standards are to be evaluated in accordance with IWL-3300 "Evaluation" and described in an engineering evaluation report. The report is to include an evaluation of whether the concrete containment is acceptable without repair of the item and if repair is required, the extent, method, and completion date of the repair or replacement. The report also identifies the cause of the condition and the extent, nature, and frequency of additional examinations. Subsection IWL also provides repair procedures to follow in IWL-4000. This includes requirements for the concrete repair, repair of reinforcing steel, and repair of the post-tensioning system. As discussed in the appendix to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

8. ***Confirmation Process:*** When areas of degradation are identified, an evaluation is performed to determine whether repair or replacement is necessary. As part of this evaluation, IWL-3300 specifies that the engineering evaluation report include the extent, nature, and frequency of additional examinations. IWL-4000 specifies the requirements for examination of areas that are repaired. Pressure tests following repair or modifications are in accordance with IWL-5000. As discussed in the appendix to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.

9. ***Administrative Controls:*** IWA-1400 specifies the preparation of plans, schedules, and inservice inspection summary reports. In addition, written examination instructions and procedures, verification of qualification level of personnel who perform the examinations, and documentation of a quality assurance program are specified. IWA-6000 specifically covers the preparation, submittal, and retention of records and reports. As discussed in the appendix to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ***Operating Experience:*** ASME Section XI, Subsection IWL was incorporated into 10 CFR 50.55a in 1996. Prior to this time, operating experience pertaining to degradation of reinforced concrete and prestressing systems in concrete containments was gained through the inspections required by 10 CFR Part 50, Appendix J and ad hoc inspections conducted by licensees and the Nuclear Regulatory Commission (NRC). Recently, NRC Information Notice (IN) 99-10 described occurrences of degradation in prestressing systems. The program is to consider the degradation concerns described in this generic communication. Implementation of Subsection IWL, in accordance with 10 CFR 50.55a, is

a necessary element of aging management for concrete containments through the period of extended operation.

References

10 CFR Part 50, Appendix J, *Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors,* Office of the Federal Register, National Archives and Records Administration, 2005.

10 CFR 50.55a, Codes and Standards, Office of the Federal Register, National Archives and Records Administration, 2005.

ACI Standard 201.1R-77, *Guide for Making a Condition Survey of Concrete in Service,* American Concrete Institute.

ACI Standard 349.3R-96, *Evaluation of Existing Nuclear Safety-Related Concrete Structures,* American Concrete Institute.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components,* Subsection IWA, *General Requirements,* 2001 edition including the 2002 and 2003 Addenda, The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components,* Subsection IWE, *Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Power Plants,* 2001 edition including the 2002 and 2003 Addenda, The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components,* Subsection IWL, *Requirements for Class CC Concrete Components of Light-Water Cooled Power Plants,* 2001 edition including the 2002 and 2003 Addenda, The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.

NRC Information Notice 99-10, Revision 1, *Degradation of Prestressing Tendon Systems in Prestressed Concrete Containment,* U.S. Nuclear Regulatory Commission, October 7, 1999.

Appendix E

License Renewal Inspection Policy and Guidance*

USNRC Inspection Manual Chapter (MC) 2516 – Policy and Guidance for the License Renewal Inspection Programs
(Edited)

2516-01 PURPOSE

The purpose of MC 2516 is to document policy and guidance for review and inspection activities associated with the License Renewal Inspection Program (LRIP). The LRIP is the process used by Nuclear Regulatory Commission (NRC) staff, region, and consultants to verify the accuracy of the aging management programs and activities associated with an applicant's request for a renewed license for a commercial nuclear power plant beyond the initial licensing period under Title 10 of the Code of Federal Regulation, (10 CFR) Part 54.

2516-02 POLICY AND OBJECTIVES

02.01 The basic policies, excerpted from the Statements of Consideration of the License Renewal Rule, and objectives used in the development and implementation of the LRIP are as follows:

a. The NRC exists to assure that the public health and safety, the common defense and security, and the environment are protected.

b. With respect to license renewal of a commercial nuclear power plant, the NRC has established the following two basic principles:

   1. The first principle of license renewal is that with the exception of age-related degradation and possibly a few other issues related to safety only during extended operation of nuclear power plants, the existing regulatory process is adequate to ensure that the licensing bases of all currently operating plants provide and maintain an acceptable level of safety so that operation will not be inimical to public health and safety or common defense and security.

   2. The second and equally important principle of license renewal holds that the plant-specific licensing basis must be maintained during the renewal term in the same manner and to the same extent as during the original licensing term. This would be accomplished, in part, through a program of age-related degradation management.

c. An applicant for license renewal should rely on the plant's current licensing basis (CLB), actual plant-specific experience, industry-wide operating experience, as appropriate, and existing engineering evaluations to determine those systems, structures, and components that are the initial focus of the license renewal review.

d. The detrimental effects of aging affecting passive structures and components are less apparent than the detrimental effects of aging affecting structures and components that perform their intended functions with moving parts or a change in configuration or properties (active structures and components). Therefore, the aging management review of passive structures and components is needed to provide reasonable assurance that their intended functions are maintained consistent with the CLB during the period of extended operation.

e. For the purpose of license renewal, an applicant can generically exclude, from its integrated plant assessment, the aging management review of the following: 1) active structures and components, and 2) structures and components that are replaced, based on qualified life or specified time period, when the replacement frequency is less than 40 years ("short-lived"). In addition, some components are both active and passive. Components that are passive, or both active and passive, must be included within the scope of components requiring an aging management review based on the intended function(s) that is performed without moving parts or change in configuration or properties.

* Note: A copy of the related USNRC License Renewal Inspection Procedure 71002 is provided in Attachment D of the CGI Report 06-22, *Condition Monitoring of Passive Systems, Structures, and Components*

f. Postulated failures that could result from system interdependencies that are not part of the CLB and that have not been previously experienced need not be considered as part of a license renewal application (LRA). However, for some license renewal applicants, postulated failures that are part of the CLB may require consideration of more than the first level support systems.

02.02 The objectives of the LRIP are as follows:

a. The LRIP will provide the guidance for the inspection of license renewal programs, documentation, and activities necessary for the staff to make a finding that an applicant's LRA, aging management programs (AMPs), implementation activities, and on-site documentation provide reasonable assurance that the effects of aging will be effectively managed consistent with the CLB during the period of extended operation.

b. The LRIP will also provide the guidance for assessing the adequacy of implemented AMPs to effectively manage the effects of aging, consistent with the licensee's CLB, after the renewed license is issued.

2516-03 DEFINITIONS

Current licensing basis is the set of NRC requirements applicable to a specific plant and a licensee's written regulatory commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The CLB includes the NRC regulations contained in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications. It also includes the plant-specific design-basis information defined in 10 CFR 50.2 as documented in the most recent final safety analysis report (FSAR) as required by 10 CFR 50.71; and the licensee's commitments remaining in effect that were made in docketed licensing correspondence such as licensee responses to NRC bulletins, generic letters, and enforcement actions, as well as licensee commitments documented in NRC safety evaluations or licensee event reports.

Regulatory Commitment is an explicit statement made by a licensee (or applicant) to take a specific action agreed to or volunteered by a licensee, and that has been submitted in writing on the docket to the Commission.

Integrated Plant Assessment (IPA) is a licensee assessment that demonstrates that a nuclear power plant facility's structures and components requiring aging management review in accordance with §54.21(a) for license renewal have been identified and 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.

Nuclear power plant means a nuclear power facility of a type described in 10 CFR 50.21(b) or 50.22.

2516-06 LICENSE RENEWAL INSPECTION PROGRAM

06.01 Purpose.

The fundamental task of the LRIP is to ensure that there is reasonable assurance that the effects of aging will be managed consistent with the CLB during the period of extended operation. The program objectives derived from that task are as follows:

a. To provide a basis for recommending issuance or denial of a renewed license.

b. To identify weaknesses within an applicant's overall license renewal program or an individual AMP that fail to provide reasonable assurance that the applicable aging effects will be adequately managed during the period of extended operation.

c. To determine the status of compliance with 10 CFR Part 54 and other areas relating to maintaining and operating the plant such that the continued operation beyond the current licensing term will not be inimical to the public health and safety.

06.02 Independent Inspection Policy.

These inspections should be conducted in accordance with inspection procedure IP 71002. However, it is not possible to anticipate all the unique circumstances that might be encountered during the course of a particular inspection and, therefore, individual inspectors are expected to exercise initiative in conducting inspections based on their expertise and experience to assure that all the inspection objectives are met. If in the course of conducting an inspection, current potential safety concerns or compliance issues outside the scope of the procedure being executed are identified, the concerns should be pursued to the extent necessary to understand the issue and then they will be turned over to the Senior Resident Inspector for further follow-up inspection.

06.03 License Renewal Review Program.

The license renewal review program consists of an LRA review and site inspections. The LRA review is primarily a headquarters review performed by NRR to ensure that the applicant meets the technical and regulatory requirements of the rule, and to verify that the format and content of the application meet the requirements of the rule. The regional staff and inspection team members will become familiar with the LRA in preparation for inspections to provide operational and performance input in the application review, to assess the applicant's commitments against their past performance and experience, and in preparation to provide a regional recommendation to grant or deny approval for the applicant's request for a renewed license.

06.04 Site-Inspections.

The site inspections are assessments of an applicant's implementation of and compliance with 10 CFR Part 54 requirements. All inspection teams will be led by the regions and any NRR supporting staff will be detailed to the region for the period of time necessary to prepare, inspect, and document inspection activities. The site inspections will be performed by a team inspection in the areas of the scoping and screening activities, observation of the condition of plant equipment, and implementation of the aging management programs and review of associated documentation. By observing the current condition of plant equipment in the scope of license renewal, inspectors may identify the |effects of aging not previously recognized. Such observations allow the inspectors to evaluate the success of previously implemented plant programs, which are being credited for license renewal AMPs. The site-inspection activities will be performed using IP 71002 "License Renewal Inspections."

06.05 Post Renewal Site-Inspections.

Site inspections of AMP implementation conducted after the approval of the renewed license will be conducted in accordance with IP 71003 "Post-Approval Site Inspection for License Renewal." These inspections will verify the licensee's continued compliance with 10 CFR Part 50 and implementation of commitments related to the LRA.

06.06 Inspection Documentation.

Inspections will be documented with inspection reports sent to the applicant and made publicly available in ADAMS. Attachments to IMC 2516 provide guidance on the preparation of documents related to the site inspection. Attachment 1, "Region Notification of Plant Readiness For License Renewal," provides a region with guidance on how to prepare its overall evaluation of inspection activities performed on an applicant for license renewal. Attachment 2, "Sample License Renewal Inspection Letter," is a sample letter of an overall evaluation of the inspection completion. The results of site team inspections will provide major input for the staff and regional recommendations to grant or deny an applicant's request for a renewed license.

Appendix F

Nuclear Related Aging Management and Life Extension Abbreviations and Acronyms

Abbreviation or Acronym	Description
AMP	Aging Management Program
AMR	Aging Management Review
ANSI	American Nuclear Standards Institute
ASME	American Society of Mechanical Engineers
BAW	Babcock and Wilcox
BIR	Benefit to Investment Ratio
BOP	Balance of Plant
BWROG	Boiling Water Reactor Owners Group
CBA	Cost Benefit Analysis
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CLB	Current Licensing Basis
CUF	Cumulative Usage Factor
DBD	Design Basis Document
DOE	U.S. Department of Energy
EPIX	Equipment Performance and Information Exchange
EPRI	Electrical Power Research Institute
EQ	Environmental Qualification
ER	Environmental Report
FHA	Fire Hazards Analysis and Fire Protection Program
FSAR	Final Safety Analysis Report
FSD	Functional System Description
GALL	Generic Aging Lessons Learned
IOE	Industry Operating Experience
INPO	Institute of Nuclear Power Operations
ISG	Interim Staff Guidance
ISI	In-Service Inspection
LCM	Life Cycle Management
LRA	License Renewal Application
LRR	License Renewal Rule
MIC	Microbiological Influenced Corrosion
MPFF	Maintenance Preventable Functional Failure
MR	Maintenance Rule
NEI	Nuclear Energy Institute
NMAC	Nuclear Maintenance Assist Center
NPAR	Nuclear Plant Aging Reports
NPV	Net Present Value
NRC	Nuclear Regulatory Commission (also USNRC)
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
PdM	Predictive (diagnostic) Maintenance

Abbreviation or Acronym	Description
PM	Preventive Maintenance
PRA	Probabilistic Risk Analysis
RAI	Request for Additional Information (NRC Questions)
RAW	Risk Achievement Worth
RMPFF	Repetitive MPFF
RRW	Risk Reduction Worth
SER	Safety Evaluation Report
SOC	Statement of Considerations
SPV	Single Point Vulnerability
SRP	Standard Review Plan
SRP-LR	Standard Review Plan for License Renewal
SSC	Systems, Structures and Components
TLAA	Time Limited Aging Analyses
USNRC	United States Nuclear Regulatory Commission
WANO	World Association of Nuclear Operators

Appendix G

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