Planning for Extended Operation – License Renewal Implementation and Life Cycle Management

Author: Mr. Daniel F. Lehnert, Company Principal, LCM Technology, L.C.

CAREER SYNOPSIS

Mr. Lehnert has devoted a large part of his professional career to the design, licensing and maintenance of nuclear plants. He has led industry life cycle management and license renewal programs to develop generic criteria, methods, and procedures. These methods and procedures have included the application of license renewal rule requirements and the Nuclear Energy Institute Guideline to determine the systems, structures, and components (SSCs) in the scope of the rule, their intended functions, and the structures and components that require aging management review; perform integrated plant assessments; and evaluate time-limited analyses. He has managed large projects whose objectives were to perform an integrated assessment of the remanent life and effectiveness of current programs for all the systems, structures, and components in the plant. He has participated in domestic and international activities to develop methodology and to assist utilities with their efforts to perform life cycle management evaluations of a variety structures, components and component groupings.

ABSTRACT

Justifying that nuclear plants can be safely and economically operated for up to 20 years of extended operation has become common practice in the United States (US) and is emerging as desirable strategy in many other countries. More than 30% of the US nuclear plant fleet has obtained an extended operating license using the License Renewal Rule (10 CFR Part54). Most of the remaining US plants have applications under review by the Nuclear Regulatory Commission (NRC), in preparation, or have notified the NRC of their intent to submit applications. By most measures, the License Renewal Rule is considered a workable and successful rule. In other countries, rules affecting extended operation are evolving; however, the principal of demonstrating that aging related degradation and time-limited aging issues can be successfully managed by existing or enhanced plant programs / practices appears to be a common theme.

Obtaining the extended operating license or permit can be thought of as the first step in a long-term strategic plan for a nuclear power plant. The next steps involve (1) managing and implementing the commitments identified during the license renewal process and (2) optimizing long-term maintenance management plans and resources to achieve optimal plant performance, reliability, safety and value. These steps are commonly referred to as license renewal implementation and life cycle management.

There are three, key phases to license renewal implementation: (1) making the physical changes to plant procedures, (2) performing the actual inspections and other actions identified in the License Renewal Application (i.e., the commitments), and (3) interacting with the regulator during an inspection performed prior to the period of extended operation. Operating experience reviews to identify and review aging management issues are also part of the implementation process. Several US utilities are actively engaged in implementation activities and a few expected to be inspected by the NRC this year.

Life Cycle Management (LCM) is an integral part of effective long term maintenance planning. The objective is to minimize unplanned capability loss and optimize maintenance programs and capital investments consistent with plant safety and operating strategies / goals. The associated process is particularly effective in pulling together the relevant industry research and operating experience, benchmarking plant-specific and industry maintenance practices and operating experience, recognizing plant-specific vulnerabilities (e.g., lost revenue, consequential functional failure costs / liabilities, regulatory inspection / enforcement), opportunities for improvement, and developing near and long-term alternatives. The alternatives are economically evaluated to determine the resource and capital forecasts and identify alternatives with the lowest cost and highest reliability. The evaluations include net present value (NPV) cost analyses, benefit to cost ratio determinations, and sensitivity and uncertainty analyses. Several US utilities have aggressively applied the life cycle management process to a cross-section of critical / important structures, components and component groupings.

The US license renewal implementation and life cycle management processes and experience are discussed in this paper.

INTRODUCTION

More than 30% of the US nuclear plant fleet has obtained an extended operating license using the License Renewal Rule [1]. Most of the remaining US plants have applications under review by the NRC, in preparation, or have notified the NRC of their intent to submit applications. By most measures, the License Renewal Rule is considered a workable and successful rule. In other countries, the rules affecting extended operation are evolving; however, the principal of demonstrating that aging related degradation and time-limited aging issues can be successfully managed by existing or enhanced plant programs / practices is a common theme.

Combining this success with the substantially improved plant capacity factors has lead utilities to re-think their long-term strategic asset management plans (i.e., 40 years and beyond) and provided the confidence to aggressively implement these plans. Although, in reality, the license renewal and structure / component performance and condition management activities need to proceed in parallel, obtaining the extended operating license or permit is typically thought of as the first step in implementing a long-term strategic asset management plan for a nuclear power plant. The next steps involve (1) managing and implementing the commitments identified during the license renewal process and (2) optimizing long-term maintenance management plans and resources to achieve optimal plant performance, reliability, safety and value. These steps are commonly referred to as license renewal implementation and life cycle management and are discussed in this paper.

LICENSE RENEWAL IMPLEMENTATION

The License Renewal Rule [1] provides for a maximum license extension of 20 years and successive applications are permitted in 20-year increments. It is founded on two principles. The first principle is that, with the possible exception of the effects of aging on certain plant systems, structures and components in the period of extended operation, the regulatory process is adequate to ensure that the Current Licensing Basis (CLB) of all currently operating plants will provide and maintain an acceptable level of safety. The second and equally important principle 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. Using these principles, the Rule focuses on the effects of aging on certain long-lived passive structures and components and the time-limited aging analyses (TLAAs). The other issues, structures, and components will be adequately addressed by continuing the regulatory process and licensing basis during the extended operating period. For example, continued implementation of the Maintenance Rule will be adequate to maintain the performance and reliability of active components during the extended operating period.

Demonstrating that the effects of aging of an SC are adequately managed is called an aging management review (AMR). Specifically, the passive, long-lived structures, components and commodity groups identified in a screening process are reviewed to determine that the effects of aging are being managed such that the intended functions of the SSCs will be preserved consistent with the CLB for the period of extended operation. The results of the AMRs include a description of the programs / activities, as well as any changes to the CLB and plant modifications that are relied upon to demonstrate that the intended functions will be adequately maintained despite the effects of aging.

There are three significant regulatory documents that guide both the NRC and industry in the implementation of the Rule: (1) NUREG-1800, the Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, (2) Regulatory Guide 1.188, the Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses, and (3) NUREG-1801, the Generic Aging Lessons Learned (GALL) Report. The GALL report generically evaluates many of the existing industry programs to document the basis for determining when such programs are adequate without change and when they should be augmented for license renewal.

The utilities compile the results of their AMRs and TLAAs in an application that is reviewed by the NRC. As necessary, the applications identify commitments (typically, 50 - 70) to implement new programs or make changes / enhancements to existing programs to ensure that the effects aging will be managed during the extended operating term. Implementing these commitments is referred to as license renewal implementation.

There are three, key phases to license renewal implementation: (1) making the physical changes to plant procedures, (2) performing the inspections and other actions identified in the LRA, and (3) interacting with the regulator during an inspection performed prior to the period of extended operation. Operating experience reviews to identify and review aging management issues are also part of the implementation process. In practice, the implementation process consists of:

1. Developing a plan or strategy for the development and performance of license renewal plant aging management activities. The plant should also consider adding a license renewal implementation coordinator as early as possible to coordinate development of implementation activities, provide input to the periodic health reports and report the status of aging management implementation activities.
2. Developing a schedule for the modification of existing and development of new aging management activities.
3. Revising the configuration change process to include license renewal reviews.

4. Using current processes for procedure and work order modification and development to capture of license renewal commitments (typically, 300-400 procedure markups). For each commitment, the approach is generally as follows:
    - A commitment report is generated
    - An implementation plan is prepared that describes what each commitment means and provides the basis information and references
    - The affected procedures and statements are identified, the required preventive maintenance (PM) action(s) are identified, and the specific tasks required to complete the PM action(s) are defined. A plant steering committee approach is typically used for this work and to make resource assignments.
    - The above information is typically captured in a program manual document (plant procedure type document). The plant should also consider developing a license renewal implementation handbook or program manual that describes license renewal procedures and processes.
5. Adhering to plant work control schedule for performance of the plant aging management activities. Outage work orders are reviewed to see if the planned inspections will also satisfy one-time inspection (OTI) commitments. Work orders are identified that will make normally inaccessible portions of the pressure boundary, buried SCs, and structures available for condition assessments / inspections. The goal is to take advantage opportunities.
6. Using the current corrective action program to document operating experience related to aging degradation and to evaluate and correct abnormal conditions identified during license renewal plant aging management inspections. Documentation must be maintained in accordance with Part 54.37(a) of the License Renewal Rule [1]. The normal design control process should evaluate changes in material to determine acceptability of the material for the application for the duration of the license or until planned replacement and to ensure that the component is included in appropriate programs.
7. Developing a process to address newly identified SSCs (§54.37(b) of the License Renewal Rule); that is, when (1) an existing SSC is discovered to have been inadvertently omitted from the license renewal review, (2) a change is made to the current licensing basis (CLB) or design basis such that an existing SSC begins serving an intended function in accordance with the definition of §54.4 of the License Renewal Rule, and (3) an existing SSC is newly identified through review of operating experience or by the NRC and becomes subject to an aging management review or evaluation of time-limited aging analyses in accordance with §54.21 of the License Renewal Rule.
8. Providing license renewal training. US utilities have found that license renewal training needs to be refreshed every 5 to 6 years because of personnel changes in the plant.

Some plants have been notified that the NRC will send a 5-person team to do an implementation inspection. It is expected that the NRC will focus on verifying the status of implementation commitments and reviewing / inspecting the general condition of the structures and components.

LIFE CYCLE MANAGEMENT

By their nature, electric utilities have traditionally taken a long-term view with respect managing plant material condition. This has been necessary to ensure a safe, reliable, and cost-effective supply of electricity. In this sense, plant operators have been involved with some aspects of life cycle management for decades. However, as the electric utility industry moves forward, it is necessary for utilities to be increasingly more proactive and rigorous in their life cycle management efforts in order to maintain / improve the value of the plant and to the preserve opportunity for and/or maximize the duration of extended operation. The factors that must be considered generally include:

- **Maintaining and monitoring safety margins –** This is the most important factor. Facilities that fail to achieve high safety standards and preserve safety margins place themselves at risk with respect to continued and/or extended operation. High safety standards and maintaining required safety margins are an indispensable ingredient of economic viability.
- **Reliability and availability –** This is the next most important factor. Reliable SSCs are needed to achieve high safety standards and maximize plant availability. To meet corporate production goals, plants must be available on demand for a large part of the year. It is especially important for plants to be available during those key periods of time when the price of electricity is at its peak. Decisions or unplanned maintenance that jeopardizes plant availability at any time of the year can be costly.
- **Effective use of industry best practices –** Originally, maintenance programs were largely based on equipment manufacturer, NSSS, and architect-engineer recommendations. The SSCs in the programs that received primary attention and resources were those important to safety (covered by ASME in-service inspection rules, equipment qualification requirements, etc.) and those important to reliable production (reactor coolant pumps, turbines, electrical generators, etc.). Subsequently, original maintenance programs have been adjusted to reflect operating experience, reliability centered maintenance (RCM) programs, the NRC Maintenance Rule, preventive maintenance (PM) basis projects, and INPO equipment reliability guidance. Efforts such these will undoubtedly continue and will grow in importance as the plant ages

because they cause utilities to recognize and adopt best practices, recognize and address technical obsolescence issue, evaluate and incorporate changes in technology, and changes to maintenance craft resources and skills.

- **Costs of operating and maintaining facilities –** While it is desirable to reduce costs to the extent practical, low-cost and un-conservative decisions can adversely affect plant safety and availability, and have a significant detrimental effect on the bottom line and value to the shareholder. The electric utility industry is increasingly focusing on value rather than cost. Economic evaluations should consider the revenue loss from lost power production and other consequence costs (i.e., potential regulatory sanctions, adverse public relations, unplanned capital costs, etc.) due to decreased reliability and availability and functional failures.
- **Extended operation –** The successful application of the License Renewal Rule has opened the door to planning for extended operation (60 years and beyond). The Rule provides the ticket; implementing the license renewal commitments and addressing the above factors are means to achieving and maximizing the benefit of extended plant operation.

The Life Cycle Management (LCM) methodology and process developed by EPRI [2] has become an integral part of effective long term maintenance planning. License renewal addresses aging management of passive components and structures important to safety, whose failure could affect safety-related components, and / or whose function is required to comply with certain, regulated events. The scope of LCM includes these, plus active and passive components whose aging or obsolescence could have a significant negative impact on plant value in terms of repairs, replacements, and lost power production. Examples include balance-of-plant SSCs and/or functions that are important to production. The LCM process is particularly effective in pulling together the relevant industry research and operating experience, benchmarking plant-specific and industry maintenance practices and operating experience, recognizing plant-specific vulnerabilities (e.g., lost revenue, consequential functional failure costs / liabilities, regulatory inspection / enforcement), opportunities for improvement, and developing near and long-term alternatives (all of which meet the required safety and plant availability criteria). The alternatives are economically evaluated to determine the resource and capital forecasts and identify alternatives with the lowest cost and highest reliability. The evaluations include net present value (NPV) cost analyses, benefit to cost ratio determinations, and sensitivity and uncertainty analyses.

The LCM process results in LCM plan for an SC or an SC grouping. An LCM plan consists of activities (preventive maintenance, predictive maintenance, corrective maintenance, redesign, etc.), schedules for these activities, and projections of long-term expenditures. The alternatives for the SC are described in detailed and the life time costs are evaluated and compared. The recommended alternative is identified and the actions required to implement the alternative are described.

Several US utilities have aggressively applied the life cycle management process to a cross-section of critical / important SCs. A partial listing of the LCM plans that have been prepared is provided in the table below. Future development of the LCM technology will likely need to include methodology and tools to conveniently roll-up SC-level LCM plan recommended alternatives to forecast the plant level (or total plant) resource and capital costs and to evaluate options for moderating peaks in resource / capital costs.

Partial Listing of Life Cycle Management Projects Performed in the US

No.	Structure, System or Component Group	Plant	Scope of the LCM Assessment
1	480 VAC Station Auxiliary System	Prairie Island	Motor controllers (MCC Buckets), bus breakers, transformers, buses, voltage regulators, fuses and other electrical components
2	4160 Volt Electrical System	Fort Calhoun	Main step-up transformer, auxiliary power transformers, house service power transformer, relays, cables and switchgear (4kV breakers)
3	Chilled Water System	Virgil C. Summer South Texas Project	Safety-related chilled water system - centrifugal mechanical chillers, chilled water pumps, refrigerant dryers, heat exchangers, tanks / accumulators, filters, strainers, valves, piping and supports, and instrumentation and electrical components
4	Circulating Water Systems	Comanche Peak Diablo Canyon Fort Calhoun South Texas Project Wolf Creek	Circulating water pumps and motors, inlet and discharge valves, waterbox isolation valves, expansion joints, and trip devices whose failure could trip the system, pump or motor

Partial Listing of Life Cycle Management Projects Performed in the US			
No.	**Structure, System or Component Group**	**Plant**	**Scope of the LCM Assessment**
5	Closed Cooling Water System Heat Exchangers	Virgil C. Summer	Shell, tubes, tube sheets and supports, local valves, heat changer supports and foundation, and component cooling and service water instrumentation for measuring, detecting and/or monitoring temperature and water flow
6	Plant Doors and Hatches	Callaway	Containment hatches and plant doors that in addition to egress, also provide one or more of the following functions: fire barrier, pressure resistant, watertight, high-energy line break mitigation, missile resistant and radiation shielding
7	Emergency Diesel Generators	Wolf Creek	Diesel engine, governor, diesel gauge and control panel, electric generator, static voltage regulator, on-engine components fuel system components, and the engine cooling, lubrication, starting air, and combustion air systems
8	Feedwater Systems	Fort Calhoun	Feedwater, Condensate, Heater Vents and Drains, and Feedwater Regulating Systems (pumps, motors, coolers, heaters, tanks and control, regulating and isolation valves)
9	Instrument (Control) And Service Air Systems	Prairie Island Salem Virgil C. Summer	Reciprocating station air compressors, aftercoolers, moisture separators, air receivers, instrument air headers, distribution piping, valves and instrumentation
10	Inverters	Callaway South Texas Project Wolf Creek Nuclear	Safety and non-safety related inverters with 2.0 KVA to 25 KVA rating
11	Large Electric Motors	Comanche Peak Diablo Canyon South Texas Project Wolf Creek Monticello	Medium voltage (4 KV) constant speed, induction AC, horizontal or vertically mounted, continuous and standby duty motors, including the: ▪ Motor components / parts included the frame / housing, stator, rotor, bearings, oil reservoirs, windings, insulation system, electrical connections, terminals ▪ Local / built-in controls, diagnostics and protective devices, CTs and miscellaneous accessories ▪ Motor air cooling and filtration / conditioning ▪ Motor bearing oil cooling / preservation systems ▪ Motor space heating
12	Liquid Waste Processing and Solid Waste Management Systems	Diablo Canyon Comanche Peak South Texas Project Wolf Creek	Radwaste system components (structural, mechanical and electric / I&C) used for collecting, processing, packaging and temporarily storing the wet and solid radioactive wastes (including spent ion exchanger resins, expended liquid filter cartridges, and other miscellaneous liquid and solid wastes) generated by plant operations until shipment offsite for permanent disposal.
13	Low and Medium Voltage Breakers, Low Voltage 480V Molded Case Circuit Breakers (MCCBs)	Callaway Comanche Peak Hope Creek Prairie Island Salem South Texas Project Wolf Creek	Circuit breakers / switchgear and motor control centers in safety and non-safety related, critical and non-critical service, low and medium voltage distribution systems (240/480 Volt AC/DC and 4.16/13.8 KV AC)

Partial Listing of Life Cycle Management Projects Performed in the US			
No.	**Structure, System or Component Group**	**Plant**	**Scope of the LCM Assessment**
14	Main Condensers	Virgil C. Summer Wolf Creek	Main condenser (intermediate and low pressure condenser sections), including the shell, hotwell, tube sheets, tube bundles and tube supports/stakes, water boxes and cross-around piping for the high, expansion joints (next to the water box entry) and the turbine neck expansion joints (dog bones), and extraction steam piping
15	Main Generator	Fort Calhoun	Generator frame or casing; stator winding, including phase connections and winding support system; lead extensions and terminals; stator core, or magnetic core; rotor winding, including copper conductors and insulation system; rotor forging, gas-circulating fans; retaining rings; bearings; hydrogen coolers; hydrogen seals; and exciter with static rectifier and analog voltage regulator
16	Main Steam And Feedwater Isolation Valves	Wolf Creek	Valve and hydraulic actuator components
17	Nuclear Instrumentation	Prairie Island	Source range, intermediate range and power range detectors with amplifiers and other electronic components
18	Piping Susceptible To Flow Accelerated Corrosion (FAC)	Wolf Creek	All piping susceptible to flow accelerated corrosion
19	Radiation Monitoring	Virgil C. Summer Comanche Peak (2006)	General area monitors, liquid monitors, and airborne monitors
21	Reactor Protection	Wolf Creek	Westinghouse 7300 and SSPS equipment
22	Steam Generator Blowdown and Cleanup (SGBD)	Comanche Peak	The SGBD system components (mechanical and electrical / I&C) is used to cool, depressurize, filter and remove dissolved solids and radionuclides by filtration and ion exchange from the steam generator blowdown.
23	Water Treatment And Potable Water Systems	Comanche Peak	Water treatment system components: surface water, feed and filtered water forwarding pumps, solids contact clarifier, surge tank, pressure filter, filtered water storage tank., multi-media filters Potable water: booster pumps, hydro-pneumatic tank and piping headers and distribution system

CONCLUSION

Justifying that nuclear plants can be safely and economically operated for up to 20 years of extended operation has become common practice in the United States (US) and is emerging as desirable strategy in many other countries. Thirty percent of the US nuclear plant fleet has obtained an extended operating license and most of the remaining US plants have applications under review by the Nuclear Regulatory Commission (NRC), in preparation, or have notified the NRC of their intent to submit applications. Combining this success with the substantially improved plant capacity factors has lead utilities to re-think their long-term strategic asset management plans (i.e., 40 years and beyond) and provided the confidence to aggressively implement these plans. License renewal implementation and life cycle management provide the means to implement these plans. There are three, key phases to license renewal implementation: (1) making the physical changes to plant procedures, (2) performing the inspections and other actions identified in the license renewal application, and (3) interacting with the regulator during an inspection performed prior to the period of extended operation. The Life Cycle Management (LCM) methodology and process developed by EPRI [2] has become an integral part of effective long term maintenance planning. The LCM process results in LCM plan for an SC or an SC grouping. An LCM plan consists of activities (preventive maintenance, predictive maintenance, corrective maintenance, redesign, etc.), schedules for these activities, and projections of long-term expenditures. Several US utilities have aggressively applied the life cycle management process to a cross-section of critical / important SCs.

REFERENCES

1. US NRC 10 CFR 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," 60 FR 22491, May 8, 1995.
2. EPRI Technical Report 1000806, "Demonstration of Life Cycle Management Planning for Systems, Structures and Components" With Pilot Applications at Oconee and Prairie Island Nuclear Stations, January 2001.