

NPP License Renewal and Aging Management: An International Perspective

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ABSTRACT

There are 103 licensed, operating commercial nuclear power plant (NPP) reactors in the United States today. At present there are over 400 operational NPPs in the International Atomic Energy (IAEA) Member States. Many of these operating NPPs are approaching the end of their original operating license; license renewal and the possibility of long-term operation (LTO) are topics of increasing interest. The extensively documented license renewal program within the United States is currently going through an evolution towards attributable information available through both hardcopy reference documents and relational databases. This process could be improved by broader technical knowledge gained from international operating experience and, reciprocally, may provide valuable insight for beneficial multilateral efforts. Other countries are conducting similar NPP inspections, audits, and monitoring, without observing unanticipated LTO-related degradation. This knowledge of international experience provides added assurance of the effectiveness of the aging management programs (AMPs) that have been implemented.

Based on the Atomic Energy Act of 1954, the U.S. Nuclear Regulatory Commission (NRC) issues licenses for commercial power reactors to operate for up to 40 years and allows these licenses to be renewed. The NRC has developed a license renewal process, establishing the technical and administrative guidelines for renewal of operating power plant licenses, that can be completed in a reasonable period of time with clear recommendations to assure safe power operation of nuclear plants for an additional 20 years. The applicant must demonstrate that programs are in place to manage those aging effects applicable to the passive, long-lived plant structures and components. The safety review also verifies that design and analysis conclusions based on the current operating term have been evaluated and are valid for the 20-year extended period of operation. As of July 2005, the NRC has renewed the operating licenses for 19 nuclear plant sites (33 reactor units).

The NRC has developed a number of internationally available license renewal guidance documents to describe the interrelated aspects of preparing and reviewing license renewal applications. As an example, the Generic Aging Lessons Learned (GALL) Report catalogs plant structures and components; lists the materials, environments, aging effects and mechanisms; and documents how existing commonly used plant programs can be used or enhanced to mitigate or manage these aging effects. The NRC is incorporating lessons learned from reviews and audits conducted by the staff to update the guidance documents to support and improve the process. These documents, originally published in 2001 are being revised to incorporate lessons learned from the reviews and audits of recently submitted license renewal applications.

The NRC is also using this license renewal experience to focus on significant age-related issues. For example, the NRC has assembled both foreign and domestic information concerning nickel alloy penetration nozzle cracking and boric acid corrosion. International operating experience has demonstrated that nickel alloys at dissimilar metal weld connections in the reactor coolant system of pressurized water reactor (PWR) plants may be susceptible to primary water stress corrosion cracking (PWSCC). The NRC has several ongoing activities that address inspection of nickel alloy components susceptible to PWSCC. Aging management programs in the updated GALL Report are being improved and expanded to provide improved assurance for safe long term operation.

1. BACKGROUND

Three of the five major goals of the NRC are to ensure protection of the public health and safety, ensure openness in our regulatory process, and ensure that NRC actions are effective, efficient, realistic, and timely [1]. These goals are reflected in the NPP license renewal emphasis on openness and efficiency as well as safety. The primary consideration in the NPP license renewal process is to ensure that the effects of aging are monitored, managed, and controlled such that safety is ensured for the renewal period. The NRC openly shares the U.S. experience by placing appropriate technical references and topical information on its website (<http://www.nrc.gov/reactors/operating/licensing/renewal.html>).

The NRC staff has prepared license renewal guidance (LRG) documents to aid in the development and review of license renewal applications (LRAs) per the license renewal rule [3], 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." Such guidance documents provide a method for systematic review of plant aging information in order to assess materials and component aging issues related to continued operation and license renewal of operating reactors. Literature on mechanical, structural, and thermal-hydraulic components and systems reviewed consisted of Nuclear Plant Aging Research (NPAR) reports, NRC Generic Letters, Information Notices, Licensee Event Reports (LERs), Bulletins, NUMARC Industry Reports (IRs) and literature on electrical components and systems. The results of these reviews were systematically analyzed and presented in the first GALL Report in 1996 [4]. This document was then expanded upon to provide credit for existing plant programs, thus becoming the 2-volume 2001 version of the GALL Report which is used as a reference by license renewal applicants and regulators [5]. The 2001 GALL Report updated the knowledge base to include all aging-related events reported in the LERs up to 1998 and expands the scope to include evaluation of existing plant programs to determine whether any of the commonly used plant programs can be acceptable as adequate aging management programs for the identified aging effects. Concurrently in 2001 [6], NRC published the standard review plan for review of license renewal applications for nuclear power plants (SRP-LR) and the Regulatory Guide (RG) 1.188, "Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses," which endorses [7] the Nuclear Energy Institute (NEI) guidance in NEI 95-10, Revision 3, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule" [8]. The SRP-LR sections are keyed to RG-1.188; the sections are numbered correspondingly. All four documents [9,10,11,12] are being revised to incorporate lessons learned from operating experience and license renewal application reviews since the original publication of the documents [13].

During the review process, the applicant must demonstrate that programs are in place to manage those aging effects to which the passive, long-lived structures and components of the plant are subjected. The review also verifies that analyses that are based on the current operating term have been evaluated and are shown to be valid for the additional 20-year period of extended operation. This paper describes the development and evolution of this LRA review process.

2. EXTRAPOLATING AMERICAN EXPERIENCE

There are 103 licensed, operating commercial nuclear power plant (NPP) reactors in the United States today. At present there are over 400 operational NPPs in the International Atomic Energy (IAEA) Member States. Many of these operating NPPs have been operating for decades; the possibility of long-term operation is an issue of critical concern. Operating experience has shown that ineffective control of the aging degradation of major NPP components can jeopardize plant safety and life [14]. Safety is affected by what happens at the plant. Reactors start to appear very similar when reduced to functions, components, materials, environment, and aging effects and mechanisms [15]. The effort for safe LTO also appears more consistent when different designs are conceptually visualized as aging management and monitoring needs that must be met to ensure safety.

Countries are at different stages of addressing this topic of long-term operation. The extensively documented license renewal program within the United States [2], by virtue of the size and age of U.S. nuclear power plants, is currently going through an evolution towards attributable information available through both hardcopy reference documents and relational databases (Figure 1). This process could be

improved by broader technical knowledge gained from international operating experience and, reciprocally, may provide valuable insight for beneficial multilateral efforts. Other countries are conducting similar NPP inspections, audits, and monitoring, without observing unanticipated LTO-related degradation. This knowledge of international experience provides added assurance of the effectiveness of the aging management programs (AMPs) that have been implemented.

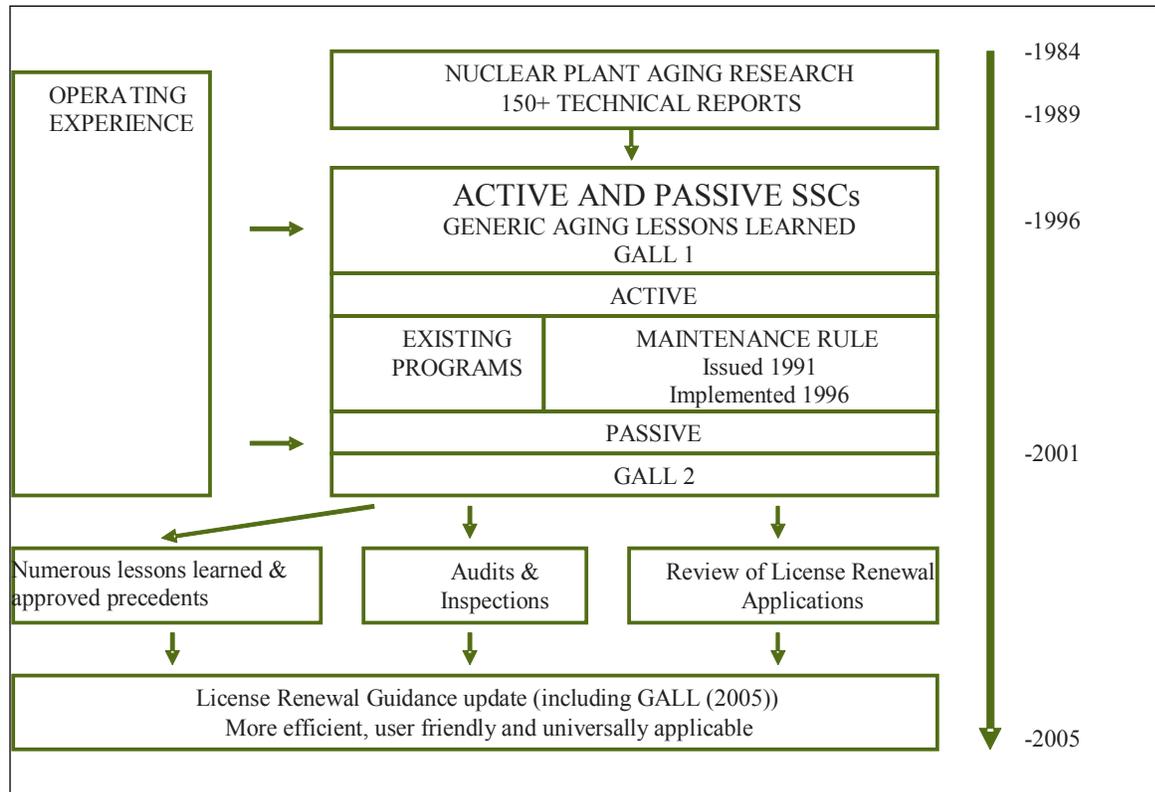


Figure 1. Evolutionary process in the United States for developing NPP license renewal guidance and long-term reactor operation (adapted from [15]).

A preliminary comparison of the periodic safety review process and NRC's regulatory and oversight process indicates many similarities [17, 18]. PSRs are comprehensive assessments to: (i) determine, at the time of the review, whether the plant complies with its licensing basis; (ii) identify the extent to which the current licensing basis remains valid, in-part, by determining the extent to which the plant meets current safety standards and practices; (iii) provide a basis for implementing appropriate safety improvements, corrective actions, or process improvements; and (iv) provide confidence that the plant can continue to be operated safely. These PSR objectives are substantively accomplished in the United States on an ongoing basis [18]. NRC's regulatory process provides a robust foundation for ongoing assessments, evaluations, and when appropriate, imposition of new requirements. NRC and the U.S. nuclear industry have a 30-year history of implementing broad-based plant assessments. As shown in Fig. 2, the US regulatory and oversight process is based upon a cycle of operational experience, regulations & guidance, licensing & certification, and oversight with advisory adjudication, research, and advisory activities as the hub [17].

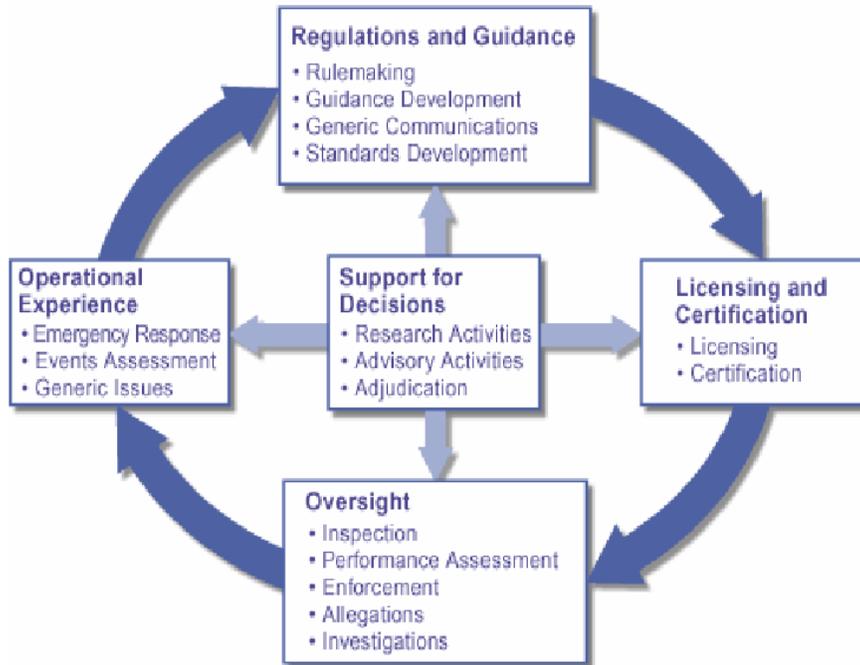


Figure 2. Overview of US regulatory and oversight process (from [17]).

3. LICENSE RENEWAL REVIEW PROCESS

The LR process proceeds along two tracks -- one for review of safety issues (10 CFR Part 54) and another for environmental issues (10 CFR Part 51) [3,19]. The Statement of Considerations [20] provides a final rule detailing revisions in 10 CFR Parts 2, 51, and 54 pertaining to nuclear power plant license renewal. An applicant must provide the NRC with an evaluation that both addresses the technical aspects of plant aging and describes the ways those effects will be managed. It must also prepare an evaluation of the potential impact on the environment if the plant operates for another 20 years. The NRC staff reviews the application and verifies the safety evaluations through inspections [21].

The license renewal rule rests on the determination that current operating plants continue to maintain an adequate level of safety and, that over the plant life, this level has been enhanced through maintenance of the current licensing basis (CLB), with appropriate adjustments to address new information from industry operating experience. Additionally, regulatory activities have provided ongoing assurance that the CLB will continue to provide an acceptable level of safety. There are two major safety assessments that an applicant must perform and submit in a license renewal application: (1) an integrated plant assessment and (2) an assessment of time-limited aging analyses (TLAAs). Typical TLAAs that must be evaluated include reactor vessel neutron embrittlement, metal fatigue, environmental qualification of electrical equipment, concrete containment tendon pre-stress, and containment liner plate and penetration sleeve fatigue [20,21].

NRC's responsibilities under the U.S. National Environmental Policy Act [22] call for a review of the impact of license renewal on the environment. In parallel with aging efforts, the NRC pursued separate rulemaking to revise its environmental regulation, 10 CFR Part 51 [19], to focus the scope of review of environmental issues. Certain issues are evaluated generically for all plants, rather than separately in each plant's renewal application. The NRC's evaluation, Generic Environmental Impact Statement for License Renewal of Nuclear Plants (GEIS) [23], assesses the scope and impact of environmental effects that would be associated with license renewal at any given NPP site. A plant-specific supplement to the generic environmental statement is required for each licensee that applies for license renewal.

Table 1: Status of Existing NPP License Renewal Applications in the U.S. (as of 7/25/05)

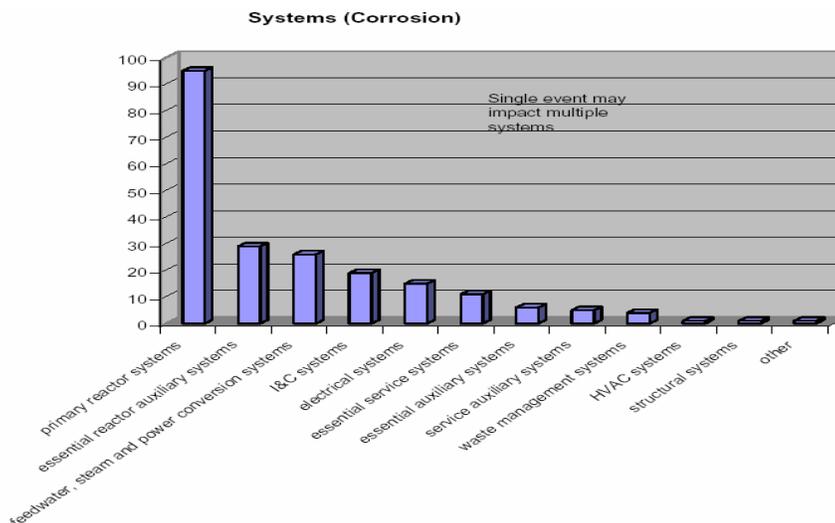
Applicant	Plant Name & Units	Plant Type	Date LRA Received	Date of SER	Date License d
Baltimore Gas & Electric Co.	Calvert Cliffs 1 & 2	PWR	Apr'98	Nov'99	Mar'00
Duke Energy	Oconee 1, 2, & 3	PWR	July'98	Feb'00	May'00
Entergy Operations	Arkansas Nucl. One 1	PWR	Feb'00	Apr'01	June'01
Southern Nucl. Operating Co. Inc.	Edwin I. Hatch 1 & 2	BWR	Mar'00	Oct'01	Jan'02
Florida Power & Light Co.	Turkey Point 3 & 4	PWR	Sept'00	Feb'02	June'02
Virginia Electric & Power	Surry 1 & 2 North Anna 1 & 2	PWR	May'01	Nov'02	Mar'03
Duke Energy	McGuire 1&2 Catawba 1 & 2	PWR	June'01	Jan'03	Dec'03
Exelon	Peach Bottom 2&3	BWR	July'01	Feb'03	May'03
Florida Power & Light Co.	St. Lucie 1 & 2	PWR	Nov'01	July'03	Oct'03
Omaha Public Power District	Fort Calhoun	PWR	Jan'02	Sept'03	Nov'03
Carolina Pwr. & Light	Robinson 2	PWR	June'02	Jan'04	Apr'04
Rochester Gas & Elec. Corp.	Ginna	PWR	Aug'02	Mar'04	May'04
SCE&G	Summer	PWR	Aug'02	Jan'04	Apr'04
Exelon	Dresden 2 & 3 Quad Cities 1 & 2	BWR	Jan'03	July'04	Oct'04
Southern Nuclear Operating Co.	Farley 1&2	PWR	Sept'03	Mar'05	May'05
Entergy Operations	Arkansas Nuclear One 2	PWR	Oct'03	Apr'05	July'05
Indiana & Michigan Power Co.	DC Cook 1&2	PWR	Nov'03	May'05	
Tennessee Valley Authority	Browns Ferry 1, 2 &3	BWR	Jan'04		
Dominion Nuclear Connecticut, Inc.	Millstone 2&3	PWR	Jan'04		
Nuclear Management Co.	Point Beach 1 & 2	PWR	Feb'04		
Constellation Energy	Nine Mile Pt 1 & 2	BWR	May'04		
Carolina Pwr. & Light	Brunswick 1 & 2	BWR	Oct'04		
Nuclear Management Co.	Monticello	BWR	Mar'05		
Nuclear Management Co	Palisades	PWR	Mar'05		
AmerGen Energy Company	Oyster Creek	BWR	July'05		

4. SEVEN YEARS OF LESSONS LEARNED

The process of power reactor license renewal has produced considerable experience in recent years, with 33 NPP operating licenses already renewed and applications for 16 additional NPPs being processed (Table 1). The NRC is nearly half-way through an anticipated 12-year cycle for license renewal, beginning with the Calvert Cliffs Nuclear Power Plant [24].

The NRC is using this experience to update the documents to support the process. The 2001 LRG documents [5,6,7,8] are being revised to incorporate lessons learned from the review of these previous LRAs [9,10,11,12]. Changes to the GALL Report and SRP-LR fall into the following categories: roll-up changes, staff positions previously approved in other documents, such as safety evaluation reports (SERs) and approved interim staff guidance (ISGs), operating experience, and technical or process clarifications or corrections. The 2001 LRG documents contained aging management reviews (AMRs) that used very explicit component identification, material nomenclature, and environment definitions. Hence, a license renewal applicant would need to justify reasons for the content of the LRA not being consistent with the content of the GALL Report. This justification would not be needed if the AMR terminology was based on more practical and consistent component groupings, material nomenclature, and environment definitions. The modification of the AMR line items with these new groupings was part of the “roll-up process.” The roll-up process also included standardizing the terminology used throughout GALL, the inclusion of certain technical criteria to further clarify the applicability of the results, reformatting, and the correction of editorial errors. Chapter IX was added to the revised GALL Report to standardize and define terminology used in the document. In addition to the roll-up changes, the revised GALL Report incorporates specific technical changes based on the incorporation of staff positions approved in previous license renewal safety evaluation reports and Interim Staff Guidance (ISGs) that could be accepted generically. In addition, tables were updated to include new material, environment, aging effect and aging management program (MEAP) combinations that are common to LRAs, including those that have already been reviewed that could be accepted generically.

An operating experience review was performed to identify AMR line items to add or modify in the GALL Report. This review included both domestic and international operating experience. The Licensee Event Reports (LERs) from American NPPs included failures, cracking, degradation, etc of passive components was reviewed by the NRC staff and contractors and used to revise the GALL Report. The international Incident Reporting System (IRS), jointly operated by the IAEA and the Nuclear Energy Agency (NEA), compiles and analyses information on nuclear power plant events and promotes a systematic approach to the feedback of lessons learned from operating experience. A preliminary analysis indicated that of the records in the IRS database, almost a third involved cracking and corrosion issues. This study also indicated operating events affected the primary reactor systems 4x more compared to other NPP systems (Fig. 3 below).



NPP events reported to the IRS are significant in terms of causes and safety lessons learned. The IRS database was queried for reports relating to passive components with corrosion and cracking. Thirty-three reports were identified since 1992 that met these criteria. These reports were analyzed to determine if there were any new AMR line items that needed to be included in the GALL Report. Many of the reports identified MEAP combinations that were already in the GALL Report or were already addressed by staff ISG documents and thus no additions were made for these. A few of the items appeared to be specific to foreign plants and thus were not generically applicable to US PWRs and BWRs and no additions were made to the GALL Report for these items. Based on our review, ultimately there were no additional MEAP combinations warranting inclusion to the GALL Report and, in general, it was concluded that the GALL Report's AMR line items were comprehensive.

The first LRA was submitted in April 1998 by Baltimore Gas & Electric Company for the Calvert Cliffs Plant, Units 1 & 2. NRC issued the first SER 20 months later in 1999. Since that first LRA, 24 additional LRAs have been submitted for 47 additional reactors (Table 1). As of June 1, 2005, the NRC has issued 17 SERs – 14 related to PWR NPPs and 3 related to BWR NPPs. In the process of studying generically consistent decisions and staff-approved positions, previous license renewal SERs were reviewed to identify instances where changes to the GALL AMR line items should be made to improve the technical accuracy and consistency of the license renewal process. Over four hundred individual items were collected from these information sources and each was reviewed for its applicability, value, and technical adequacy as part of the NRC review process. The NRC has referenced a majority of the completed SERs in the technical bases for revision to the LRG documents, NUREG-1833, [25] that will accompany the revised LRG documents.

The interim staff guidance (ISG) documents are those issued by an NRC office to clarify a Standard Review Plan or other guidance document, or to address issues not discussed in such documents. In the context of license renewal, the objective of the ISG process is to capture lessons learned from license renewal reviews and communicate them to the stakeholders. The process includes interaction with stakeholders during the development of the ISG, including publishing a Federal Register notice requesting comments. If the ISG is approved, then an applicant for a renewed license needs to address the specified issue.

After an ISG has been approved, it is incorporated into the next revision of the LRG documents under consideration (such as NUREG-1800, NUREG-1801, and Regulatory Guide 1.188). For licensees holding a renewed license, the license renewal regulations require that after the renewed license is issued, the final safety analysis report (FSAR) update must include any newly identified systems, structures, and components that would have been subject to an aging management review or evaluation of time-limited aging analyses. This FSAR update must describe how the effects of aging will be managed such that the intended function(s) will be effectively maintained during the period of extended operation. Therefore, for ISGs involving newly identified systems, structures, or components (SSCs) that would have been subject to an aging management review or evaluation of time-limited aging analyses, the regulations require a licensee holding a renewed license to submit in its next FSAR update a description of how the effects of aging will be managed.

5 UPDATED LICENSE RENEWAL GUIDANCE DOCUMENTS

This update, being completed in 2005, will incorporate lessons learned from review of license renewal applications to increase the efficiency for both applicant and NRC. <http://www.nrc.gov/reactors/operating/licensing/renewal/guidance/updated-guidance.html> There are three main documents being revised, the GALL Report [9], the SRP-LR [10], and the RG 1.188 [11]. To clarify the process and the changes, the Bases document of justification for technical changes [25] and an analysis of public comments on the improved license renewal guidance documents [26] will accompany the release of the revised license renewal guidance documents. The approach taken in this Public Comment NUREG-1832 follows that of the 659-pg NUREG-1739 that accompanied the release of guidance documents in 2001.

The GALL Report provides a generic evaluation of existing programs for the purposes of aging management for the period of extended operation. The NRC staff used this report to document the basis for determining when existing programs are adequate without change and when existing programs should

be augmented for license renewal. The GALL Report systematically catalogs aging effects on structures and components, identifies the relevant existing plant programs, and evaluates the existing programs against the attributes considered necessary for an aging management program to be acceptable for license renewal. The GALL Report, Revision 1, will be an update to the July 2001 version; the report format is expected to be largely unchanged. The adequacy of the generic aging management programs in managing certain aging effects for particular structures and components will continue to be evaluated based on the review of the following ten program elements: scope of program, preventive actions, parameters monitored or inspected, detection of aging effects, monitoring and trending, acceptance criteria, corrective actions, confirmation process, administrative controls, and operating experience. The GALL Report is a technical basis document for the SRP-LR and should be treated in the same manner as an approved topical report that is applicable generically. An applicant may reference the GALL report in a license renewal application to demonstrate that the applicant's programs at its facility correspond to those reviewed and approved in the GALL Report, and that no further NRC staff review is required.

Regulatory guides (RGs) provide guidance to applicants on implementing specific parts of NRC regulations. The current RG applicable to license renewal is RG 1.188, first published in July 2001 and currently undergoing revision. Initially released for public comment in January 2005 as draft regulatory guide (DG-1104), "Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses," proposes to endorse the guidance in NEI 95-10, Revision 6, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 - The License Renewal Rule" with a few exceptions. The document NEI 95-10, Revision 6, provides guidance on the scope of 10 CFR Part 54, scoping for aging management review, and maintenance of aging effects, as well as other issues affecting the format and content of an LRA. NEI 95-10 sections are keyed to the SRP-LR format to standardize the review.

The large number of changes made to the GALL Report required parallel changes to the SRP-LR which provides guidance to NRC staff reviewers in performing safety reviews of applications to renew licenses of NPPs in accordance with the license renewal rule (10 CFR Part 54). The principal purposes of the SRP-LR are to ensure the quality and uniformity of NRC staff reviews and to present a well-defined methodology for evaluating applicant programs and activities for the period of extended operation. The SRP-LR is also intended to make information about the regulatory process for license renewal widely available to the public and the nuclear power industry. The SRP-LR sections address which group performs the review, the matters that are reviewed, the basis for review, how the review is accomplished, and the conclusions that are sought. The SRP-LR references the GALL Report as a technical basis document for providing credit for existing programs and provides guidance to the NRC staff reviewers to focus their reviews on areas where existing programs should be augmented for license renewal or new programs proposed by an applicant. In addition to the technical and rollup changes, the SRP-LR is being revised to better reflect the methodology of performing the safety audit and reviews associated with the NRC staff review of a LRA. These changes include a better description of the work split between the NRC branches performing the safety review. This was achieved by the addition of a new section to the SRP-LR, Section 3.0, which adds a step in the safety review of the Safety Review Project Manager (PM) to assign and document work assignments dividing the AMR and AMP reviews among various NRC branches and sections.

6 EMERGING ISSUES

The NRC is also using this license renewal experience to focus on significant age-related issues. For example, the NRC has assembled both foreign and domestic information concerning nickel alloy penetration nozzle cracking and boric acid corrosion. International operating experience has demonstrated that nickel alloys at dissimilar metal weld connections in the reactor coolant system of pressurized water reactor (PWR) plants may be susceptible to primary water stress corrosion cracking (PWSCC). The NRC has several ongoing activities that address inspection of nickel alloy components susceptible to PWSCC. Reflective of the increase in understanding gained through these ongoing activities, aging management programs (AMPs) in the updated GALL Report are being improved and expanded to provide improved assurance for safe long term operation. As an example, the 2005 GALL Report has added a new AMP for nickel-alloy penetration nozzles welded to the upper reactor vessel closure heads of PWRs. This AMP is focused on managing the effects of cracking due to PWSCC of the nickel-alloy used in the fabrication of the upper VHP nozzles at PWR-designed nuclear facilities.

7 CONCLUSION

As global energy needs continue to grow, nuclear power generation will remain in the mix of energy production. Extending the operating life of existing nuclear power stations is, for some utilities, an economically feasible way to meet future energy demands. The responsibility of the NRC is to ensure that plant license renewal is safe - that it does not pose undue risk to public health and safety or to the environment. The NRC's process for concluding that a renewed operating license can be issued involves rigorous safety and environmental reviews to ensure that regulatory requirements will continue to be met in the renewal term. The license renewal guidance documents that have been described in this paper were developed as a result of equally rigorous research and evaluation. The return on this investment is a more effective and efficient methodology for developing and reviewing applications for license renewal.

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