

NPP License Renewal and Aging Management: Revised Guidance

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Abstract. Based on the Atomic Energy Act, the NRC issues licenses for commercial power reactors to operate for up to 40 years and allows these licenses to be renewed for up to another 20 years. NRC has approved license renewal for well over 50% of U.S. located reactors originally licensed to operate for 40 years. Of these 104 reactors (69 PWRs, 35 BWRs), the NRC has issued renewed licenses for 71 units and is currently reviewing applications for another 15 units. As of May 1, 2012, ten plants at nine sites had entered their 41st year of operation and thus are in their first period of extended operation (PEO). Five more plants will enter the PEO by the end of 2012. One foundation of the license renewal process has been license renewal guidance documents (LRGDs). The U.S. Nuclear Regulatory Commission (NRC) revised key guidance documents used for nuclear power license renewal in 2010 and 2011. These include NUREG-1800, “Standard Review Plan for Review of License Renewal Applications,” revision 2 (SRP-LR), and NUREG-1801, “Generic Aging Lessons Learned (GALL) Report,” revision 2 (GALL Report). The guidance documents were updated to reflect lessons learned and operating experience gained since the guidance documents were last issued in 2005.

I. Background

The Atomic Energy Act of 1954 (as amended) allows the NRC to issue licenses for commercial power reactors to operate for up to 40 years and for renewal [1]. Specifically *Section 103, Commercial Licenses, c.* states [2] that “Each such license shall be issued for a specified period, as determined by the Commission, depending on the type of activity to be licensed, but not exceeding forty years from the authorization to commence operations.” The original 40-year term for reactor licenses was based on economic and antitrust considerations--not on limitations of nuclear technology. However, some structures and components may have been engineered on the basis of an expected 40-year service life. The NRC regulations allow the renewal of these licenses for a period up to an additional 20 years, based on the outcome of an assessment to determine whether the nuclear facility can continue to operate safely and whether the protection of the environment can be assured during the 20-year period of extended operation. There are no specific limitations in the Atomic Energy Act or the NRC’s regulations restricting the number of times a license may be renewed.

A recent presentation [3] reviewed the history of nuclear power plant (NPP) license renewal in the U.S. In the early 1980s, the NRC staff recognized that it needed to identify the information required and the process to be used for determining whether to grant an extension to an operating license. The overall goal of the Nuclear Plant Aging Research (NPAR) Program established by the NRC Office of Nuclear Regulatory Research (RES) in 1985 was to understand aging and to identify ways to manage aging of safety-related systems, structures, and components (SSC) in NPPs [4]. This resulted in the publication of more than 150 technical reports (Fig. 1). Based on these results, a technical review group concluded that many aging phenomena are readily manageable and do not pose technical issues that would preclude NPP life extension. In 1986, NRC staff published a request for comment on a policy statement that would address major policy, technical, and procedural issues related to NPP license renewal. In August 1988, NRC conducted an International Nuclear Power Plant Aging Symposium with 550 participants from 16 countries and sessions on topics such as aging research programs, aging of structures and mechanical equipment, aging of electrical equipment, aging of systems and components, reliability, role of maintenance in aging management, aging of vessels and steam generators [5]. Following this, in October 1989, NRC held a public workshop on license renewal [6] to discuss the “NPAR Approach to Controlling Aging in Nuclear Power Plants” affiliated with the Seventeenth Water Reactor Safety Information Meeting and had sessions on primary systems

integrity, plant performance, testing and analysis, piping and NDE, and plant aging. Subsequently the Nuclear Management and Resources Council (NUMARC) submitted for NRC review ten industry reports (IRs) addressing aging issues associated with specific NPP SSCs.

In 1990, the NRC issued a proposed license renewal rule for public comment that addressed the safety and technical requirements for license renewal. The NRC adopted these regulations (Title 10 of the *Code of Federal Regulations* (10 CFR) Part 54, “Requirements for Renewal of Operating Licenses for Nuclear Power Plants”) [7]. NRC found that many aging effects are dealt with adequately during the initial license period. In addition, the NRC found that Part 54 did not allow sufficient credit for existing programs, particularly those under NRC’s maintenance rule (10 CFR 50 Part 65), [8] which also helps manage plant-aging phenomena. The NRC issued a supporting document [9] which, as a supplement to the Statement of Considerations for the 1991 rule, describes how the regulatory process assured that the plant-specific licensing bases provided reasonable assurance that NPP operation would not be inimical to the public health and safety to the end of the renewal period.

In 1992, the NRC staff and industry resources were redirected to address implementation issues of the license renewal rule. The NRC staff recommended that appropriate technical information and agreements from the NUMARC IRs be incorporated into the draft standard review plan for license renewal (SRP-LR). After further analysis, the NRC amended the regulations, subsequently published in May 1995 [10] to establish a regulatory process that is more efficient, more stable and more predictable than the previous license renewal rule. In particular, Part 54 was clarified to focus on managing the adverse effects of aging, especially the effects of aging on long-lived passive structures and components and time-limited aging analyses (TLAAs) as defined in 10 CFR 54.21(a)(1) (technical information in contents of license renewal application) and 54.3, (definitions) respectively. Following this, the Nuclear Energy Institute (NEI) in cooperation with the NRC, prepared NEI 95-10 (Industry Guideline For Implementing the Requirements of 10 CFR Part 54 –The License Renewal Rule) [11] to provide an acceptable approach for implementing the requirements of 10 CFR Part 54, based on industry experience.

II. Beta-Version of Generic Aging Lessons Learned Report in 1996

The generic aging lessons learned (GALL) approach to license renewal was initiated in 1996 with the publication of NUREG-1568, NUREG-1557 and NUREG/CR-6490 [12-14]. Literature on mechanical, structural, and thermal-hydraulic components and systems reviewed consisted of NPAR reports, NRC Generic Letters, Information Notices, Licensee Event Reports (LERs), Bulletins, NUMARC IRs and literature on electrical components and systems.

NUREG-1568 summarized the NRC staff observations and lessons learned from the five License Renewal Demonstration Program (LRDP) site visits performed by the staff from March 25, 1996, through August 16, 1996. The LRDP was an NEI program intended to assess the effectiveness of the NEI 95-10 guidance [11]. NUREG-1568 [12] concluded, that in general, NEI 95-10 appeared to contain most of the guidance needed for scoping, screening, identifying aging effects, developing aging management programs (AMPs), and evaluating TLAAs.

NUREG-1557 [13] was a 188 pg summary of technical information and agreements from NUMARC IRs addressing license renewal, prepared by U.S. NRC with Argonne National Laboratory (ANL). It pioneered the use of columnar alignment of aging-related degradation mechanism, aging effect, component, material, and began the development of incipient license renewal (LR) AMPs.

A few months later, a 448 pg NRC contractor report was published in which the results of these reviews were systematized using a standardized tabular format and standardized definitions of aging-related degradation mechanisms and effects [14]. Systematic review and compilation of plant aging information was prepared by ANL (mechanical, structural, and thermal-hydraulic components) and Idaho National Engineering Laboratory (INL) (electrical components and systems). Comprehensive reviews and tabular summaries were prepared for 163 NPAR reports, 31 NRC generic letters, 265

Information Notices, 87 LERs, 5 Bulletins, and 10 NUMARC reports. Major findings of the 1996 “Generic Aging Lessons Learned (GALL) review [14] included the realization that:

- Passive components are not covered by plant maintenance procedures as extensively or as thoroughly as active components.
- Aging surveillance and monitoring methods continue to be studied and developed for passive components.
- Although information on aging mechanisms and their effects continues to develop as plants age, no new, previously unknown aging mechanisms or failure modes were identified.
- Responsible degradation mechanisms in the passive components turned out to be various forms of corrosion, fatigue, and thermal stresses.

In September 1997, W.C. Liu, P.T. Kuo, and S.S. Lee of NRC published NUREG-1611[15] which reconciled the technical information and agreements resulting from NUMARC/NRC industry report reviews and the in-service inspection requirements of ASME Subsection IWE and IWL as promulgated in 10 CFR 50.55a for license renewal. They concluded that Subsections IWE and IWL of Section XI, Division 1, of the ASME Code as endorsed in §50.55a are generally consistent with the technical information and agreements reached during the IR reviews. Specific exceptions were identified and additional evaluations and augmented inspection activities for renewal were recommended (ultimately resulting in GALL AMPs XLS1, XLS2).

Seven months later, in April 1998, the first license renewal application (LRA) was received (Table 1) for Calvert Cliffs Units 1 and 2 requesting renewal for period of 20 years beyond the current expiration of midnight, July 31, 2014, for Unit 1 and midnight, August 13, 2016, for Unit 2. The LRA was evaluated using guidance contained in NUREG-1557, NUREG-1611, NUREG/CR-6490, and other technical bases documents. NUREG-1705 [16], the corresponding Safety Evaluation Report (SER), was published in Dec. 1999.

III. Revision 0 of License Renewal Guidance Documents in 2001

By staff requirements memorandum (SRM) dated August 28, 1999, in response to SECY-99-148, “Credit for Existing Programs for License Renewal,” [17] the Commission approved the staff recommendations and directed the staff to develop improved guidance documents to focus the staff’s review on areas where existing programs should be augmented. Four months after receiving the SRM, NRC staff held the first of two workshops to invite early public participation in the LRGD development process. The first workshop gathered public and industry feedback on which existing AMPs needed to be augmented for license renewal and which programs adequately managed aging effects without change. The GALL Report (NUREG-1801, [18]) documents the staff’s basis for determining which existing programs are adequate without modification and which existing programs should be augmented for license renewal. The GALL Report is referenced in the Standard Review Plan for License Renewal (SRP-LR, NUREG-1800, [19]) as a basis for determining the adequacy of existing AMPs. On August 31, 2000, NRC announced the issuance and availability of draft LRGDs for public comment including NUREG-1800, NUREG-1801, and RG 1.188 [20] and NEI 95-10, Rev. 3 (as referenced in RG 1.188)[21]. The second workshop, held Sept. 2000, obtained feedback from stakeholders on the NRC development of the above draft revised LRGDs.

As reported in NUREG-1739, [22], these meetings resulted in 1,084 comments that were received and docketed from stakeholders on or before October 16, 2000. The nuclear industry provided 860 comments, with the majority of those from NEI. The public, including public interest groups, provided 177 comments, with 125 of those comments coming from individuals representing themselves and public interest groups. Those 125 general comments were concerned with the validity of the license renewal process. The remainder of the comments (or 47 of the comments) came from the ACRS consultants. NUREG-1739 included written comments from 128 commentators, which represent comments from 101 individuals, 15 public interest groups, and 12 industry groups that responded to the request for public comments.

Following the public meetings in 1999 and 2000, the draft LRGDs [18-20] were extensively revised and published in July 2001. The knowledge base provided by the NPAR studies was expanded upon to provide credit for existing plant AMPs and further systematized to increase the LR review process effectiveness and efficiency. GALL Rev. 0 was used as a reference by license renewal applicants and regulators. This first GALL Report and the SRP-LR included all aging related events reported in the LERs up to 1998 and expanded the scope to include evaluation of existing NPP programs to determine their acceptability. In the aging management review (AMR) line items, GALL evaluates several thousand NPP systems, structures, and components (SSCs); lists the materials, and environments, identifies the significant aging effects and mechanisms; and provides an acceptable AMP for the component, generally documenting how existing commonly used plant AMPs can be used or modified to mitigate or manage these aging effects.

The SRP-LR provided guidance to NRC Office of Nuclear Reactor Regulation (NRR) staff who perform safety reviews of applications to renew NPP licenses. The GALL Report (Vols. 1 and 2) served as the technical basis document for the SRP-LR. It defines methods and AMPs acceptable to the NRC for implementing the license renewal rule 10 CFR Part 54. Regulatory Guide 1.188 (Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses) specified the general provisions, with the corresponding regulations, that apply to filing an application for a renewed license.

IV. Revision 1 of License Renewal Guidance Documents in 2005

By May 2004, when a decision was made to revise the LRGDs to incorporate lessons learned from operating experience and the previous seven years of reviewing LRAs, NRC staff had the experience of reviewing and relicensing thirteen NPPs (26 units) as shown in Table 1.

Table 1: Status of Existing NPP License Renewal Applications in the U.S. (as of 5/2004) [23]

| Applicant | Plant Name & Units | Plant Type | Date LRA Received | Date of SER | Date Licensed |
|-----------------------------------|---------------------------------|------------|-------------------|-------------|---------------|
| 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 |

As shown in Table 1 above, when the process began to revise the LRGDs, the NRC had issued 13 SERs – 11 related to PWRs and 2 related to BWRs. In the process of studying generically-consistent

decisions and staff-approved positions, previous license renewal SERs were reviewed to identify instances where changes to GALL should be made to improve technical accuracy and consistency. Over 400 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 [23, 24]. The 2005 revisions of the SRP-LR and GALL Report [25, 26] were thus accompanied by the design and creation of a Bases Document [27] which referenced a majority of the completed SERs.

As mentioned earlier, the LRGDs are used by NPP applicants to prepare their applications for license renewal, and provide associated guidance that the NRC staff uses to review the applications and to judge their acceptability. The original version of the GALL Report and the SRP-LR contained AMR tables that used explicit component identification, material nomenclature, and environment definitions. In some situations, these characterizations were more specific than technically necessary. 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. New material, environment, aging effect and aging management program (MEAP) combinations, common to LRAs, were added. The modification of the AMR line items with these new groupings was part of the “roll-up process.” GALL Chapter IX was added to the revised GALL Report to standardize and define terminology.

In addition to the roll-up changes, GALL Rev.1 incorporated specific technical changes based on the incorporation of staff positions approved in previous SERs and Interim Staff Guidance (ISGs) that could be accepted generically. To clarify the process and the changes, a Bases document [27] and an analysis of public comments [28] accompanied the revised LRGDs. RG 1.188 [29] was revised in the process of reviewing and endorsing NEI 95-10, Rev. 6 [30]. Together these five documents [25-29] contained more than 2,500 pages of tightly interrelated technical and programmatic information.

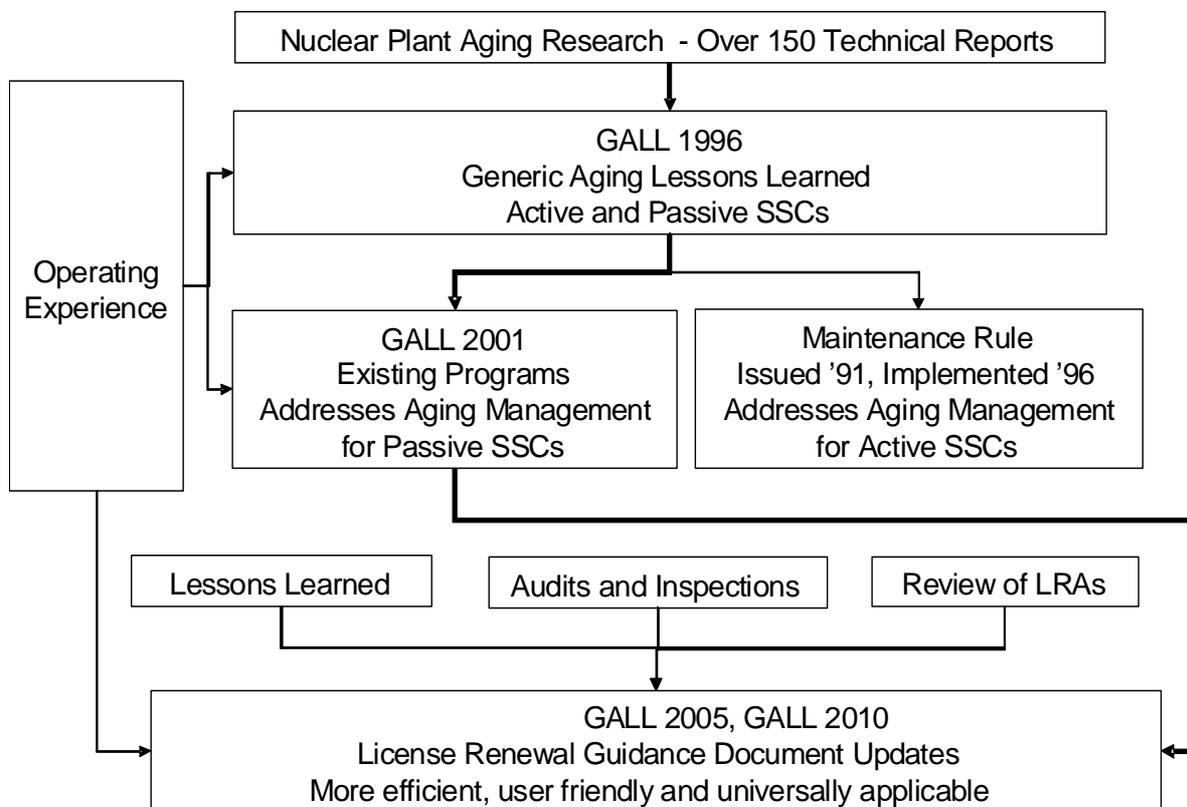


Figure 1. Summary of the Evolution of LRGDs

Table 2: American NPPs in Extended Operation by December 2012.

| Nuclear Power Plant & Unit | Entry into Extended Operation | Plant Type |
|---------------------------------------|--------------------------------------|-------------------|
| Oyster Creek 1 | 04/09/2009 | BWR-Mark 1-GE2 |
| Nine Mile Point 1 | 08/22/2009 | BWR-Mark 1-GE2 |
| Ginna 1 | 09/19/2009 | PWR-West 2LP |
| Dresden 2 | 12/22/2009 | BWR-Mark 1-GE3 |
| Robinson 2 | 07/31/2010 | PWR-West 3LP |
| Monticello 1 | 09/08/2010 | BWR-Mark1 –GE3 |
| Point Beach 1 | 10/05/2010 | PWR-West 2LP |
| Dresden 3 | 01/12/2011 | BWR-Mark 1-GE3 |
| Palisades 1 | 03/24/2011 | PWR-CE |
| Vermont Yankee 1 | 03/21/2012 | BWR-Mark 1 |
| Surry 1 | 05/25/2012 | PWR-West 3LP |
| Pilgrim 1 | 06/08/2012 | BWR-Mark1 –GE3 |
| Turkey Point 3 | 07/09/2012 | PWR-West 3LP |
| Quad Cities 1 | 12/14/2012 | BWR-Mark1 –GE3 |
| Quad Cities 2 | 12/14/2012 | BWR-Mark1 –GE3 |

V. Revision 2 of License Renewal Guidance Documents in 2010-2011

In early 2009, the NRC staff embarked on the initiative to update the SRP-LR and the GALL Report. The primary forcing functions for performing the update included the desire to: 1) capture operating experience gained since 2005, 2) integrate license renewal precedents since 2005, 3) account for changes in the NRC regulatory framework since 2005, 4) consider proposed changes identified by the nuclear industry, 5) incorporate content from license renewal ISGs, and 6) account for changes in industry codes and standards since 2005.

During the 2005 update, the focus of the staff's efforts were on the AMR line items in the GALL Report. For the 2010 update, the staff shifted their focus [31] to the AMP content. As described in the combined Public Comments/Bases document, NUREG-1950, [32] the changes in GALL Rev. 2 incorporate lessons learned from the reviews of previous LRAs, operating experience obtained after the NRC issued GALL Rev. 1, and other public input, including industry comments. More specifically, some of the changes made to the most recent version of the SRP-LR and the GALL Report [33, 34] include:

- The GALL Report is now a single volume. Supplementary documents are also combined.
- Guidance related to the ASME Code now identifies which Editions are acceptable; and clarifies how ASME Code Cases and Reliefs apply in the Period of Extended Operation (PEO).

- All AMPs were updated to reflect recent operating experience, license renewal precedents, changes in NRC regulations, content of license renewal ISGs, changes in industry codes and standards, and aligned with the revised AMP 10-element template.
- A number of further evaluation required items in the SRP-LR were eliminated based on experience or that the associated AMP was enhanced.
- New AMPs and associated AMR line items were added to address neutron absorbing materials other than Boraflex, PWR internals, and buried and underground piping and tanks.
- The scope of electrical cables addressed for inaccessible power cables not covered by environmental qualification was increased to include cables down to a nominal 400 volts.

Regulatory Issue Summaries (RIS) were subsequently released [35, 36] which addressed use of the AMRs, AMPs, and TLAAs most affected by GALL Rev. 2 including: Fatigue Monitoring (X.M1); BWR Vessel Internals (X.I.M9); Cracking of Nickel-Alloy Components and Loss of Material due to Boric-Acid-Induced Corrosion (X.I.M11B); PWR Vessel Internals (X.I.M16A); Neutron-Absorbing Materials Other than Boraflex (X.I.M40); Buried Piping and Tanks (X.I.M41); and Protective Coating Monitoring and Maintenance (X.I.S8).

Conclusion: Going into the Period of Extended Operation (PEO)

As of May 1, 2012, ten plants at nine sites have entered their 41st year of operation (Table 2) and thus are in their first PEO. Five more plants will enter the PEO by the end of 2012. As global energy needs continue to grow, nuclear power generation will remain in the mix of energy production. There is increasing industry interest in subsequent license renewal and NPP long-term operation (LTO) beyond the first PEO. Extending the operating life of existing NPPs may be, for some utilities, an economically feasible way to meet future energy demands. The responsibility of the NRC is to ensure that plant life extension is safe - that it does not pose additional 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 verify that regulatory requirements will continue to be met. The goal of this report is, that by understanding the past, NRC can better protect the future; the references mentioned in this report, and many more, are available at <http://www.nrc.gov/reactors/operating/licensing/renewal/guidance.html>

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