Assuring Safe Subsequent License Renewal for Commercial Nuclear Power Reactors in the USA

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Abstract. Renewal of licenses for operating nuclear power plants in the United States is a mature, stable process, with 86 reactors possessing renewed licenses for operation to 60 years. Using the same regulatory process as initial license renewal, the U. S. Nuclear Regulatory Commission issued guidance documents to address subsequent license renewal, for plant operation to 80 years, in July 2017. Although the license renewal (and subsequent license renewal) review is a limited scope review that focuses on managing the effects of aging for long-lived, passive structures and components in nuclear power plants during the period of extended operation, the U. S. Nuclear Regulatory Commission has in place a number of regulatory programs (e.g., the analysis of the operating experience, the Reactor Oversight Process, the generic upgrades and regulatory changes, and the use of risk informed regulation) that are integrated to ensure safe plant operation at all stages, including the initial operating license period, the period of extend operation, and the subsequent period of extended operation. The combination of the existing on-going NRC regulatory processes with the detailed license renewal and subsequent license renewal reviews will continue to ensure safe plant operation through the 80 year operating period.

1. Background

In accordance with Section 103c of the Atomic Energy Act (AEA) of 1954, as amended, nuclear power plants in the United States are licensed to operate for a term not exceeding 40 years, and may be renewed. This original 40-year license term for reactor licenses was based on economic and antitrust considerations – not on limitations of nuclear technology.

The NRC's regulations related to renewal of operating licenses for nuclear power plants are provided in Part 54 of Title 10 of the Code of Federal Regulations (10 CFR Part 54). 10 CFR 54.31(b) specifies that licenses may be renewed for a specified period not to exceed 20 years, with the renewed license term not to exceed 40 years. In addition, 10 CFR 54.31(d) states that a renewed license may be subsequently renewed in accordance with all applicable requirements, with no explicit limit to the number of "subsequent" renewals for each license.

2. Assuring Plant Safety in the First 40 Years of Operation

From a regulatory perspective, plant safety is assured throughout the first 40 years of plant operation by an interrelated combination of regulations and guidance, licensing processes, oversight activities and consideration of operating experience, which provide for adequate protection of public health and safety at every point during the plant's life. The role of operating experience is a key element because it provides valuable information to adjust our oversight activities and, when necessary, to change regulations or requirements. This is accomplished as the issues are identified for both specific and generic plant activities.

Aging management begins during the plant design and construction phases, and is accomplished through a variety of means, within the context of our existing regulatory processes. Aging management is primarily accomplished through implementation of the NRC's regulations in Part 50 of Title 10 of the U.S. Code of Federal Regulations (10 CFR Part 50) [1]. In particular, the Maintenance Rule of 10 CFR 50.65, the Quality Assurance Program of Appendix B to 10 CFR Part 50, and the requirements of 10 CFR 50.55a, Codes and standards, provide the basic framework that assures adequate aging management for both active and passive components and structures.

The Maintenance Rule focuses on monitoring and testing activities to ensure that systems, structures and components are capable of performing their intended functions. The Quality Assurance Program requirements ensure that licensees programs meet quality standards and incorporate effective corrective actions on operating experience gained from their inspection and testing. 10 CFR 50.55a focuses on implementation of consensus industry standards, for inspection and testing as well as analysis of results to inform future inspections. Other provisions to 10 CFR Part 50 also provide aging management, such as the environmental qualification of electrical equipment (10 CFR 50.49) and the reactor vessel materials surveillance program requirements (Appendix H to 10 CFR Part 50).

There are other elements of our regulatory process that provide reasonable assurance of safe plant operation. These elements include:

- Resident inspectors who are located on-site at each plant.
- Frequent inspections out of our regional offices to assess performance at each site, include such topics as plant security, emergency planning, radiation protection, environmental monitoring, and inservice inspection and testing.
- A daily assessment of plant events, both domestic and international.
- Safety issue resolutions for both generic issues and plant-specific issues.

In particular for materials aging and degradation issues that are important to safety, resolution of these issues can occur through a variety of approaches, including rule changes, generic communications, issuance of orders, and voluntary plant actions.

3. Assuring Plant Safety from 40 to 60 Years - License Renewal Review and Guidance

Plant safety in the operating period from 40 to 60 years follows the same processes and framework identified previously for the first 40 years, with the exception that additional aging management is implemented for operation beyond 40 years. The requirements to identify and implement the additional aging management are established through development of a specific regulation for license renewal, 10 CFR Part 54, “Requirements for Renewal of Operating Licenses for Nuclear Power Plants” [2]. The NRC licensing process ensures the implementation of both generic and plant-specific aging management programs (AMPs) that include operating experience to ensure components continue to perform their intended functions. The NRC’s inspection programs verify licensee implementation of the aging management programs.

The scope of license renewal includes (1) safety-related systems, structures, and components (SSCs); (2) all nonsafety-related SSCs whose failure could adversely impact functionality of safety-related SSCs; and (3) all SSCs relied on in certain safety analyses or plant evaluations for specific NRC regulations. After in-scope SSCs have been identified, those structures and components (SCs) that long-lived and passive, such as the reactor pressure vessel, steam generators, piping, seismic Category I structures, electrical cables and connections, among others, are subject to aging management review (AMR). SCs that are not subject to AMR are those that are active, such that their failure will be identified during surveillance and testing in accordance with the Maintenance Rule, or replaced on a fixed schedule.

The fundamental premise of the License Renewal Rule, provided at 10 CFR Part 54, is that the current licensing basis (CLB) for plants is adequate to ensure the safety of operating plants. In this case the CLB includes the NRC requirements applicable to a specific plant; a licensee's written commitments for ensuring compliance with and operation within the applicable NRC requirements and the plant-specific design basis; orders; license conditions;

exemptions; technical specifications; the plant-specific design-basis information documented in the most recent final safety analysis report, and the licensee's commitments remaining in effect that were made in docketed licensing correspondence such as responses to NRC bulletins, generic letters, and enforcement actions, as well as licensee commitments documented in NRC safety evaluations or licensee event reports.

A basic aspect of the License Renewal Rule is a licensee's integrated plant assessment that demonstrates that the SCs requiring AMR have been identified and the effects of aging on their functionality will be managed in order to maintain the CLB such that there is an acceptable level of safety during the period of extended operation from 40 to 60 years. License renewal also involves applicant consideration of time-limited aging analyses (TLAAs), which are those licensee calculations and analyses in the CLB for the SSCs within the scope of license renewal. Each application must include a supplement to the environmental report that complies with the requirements of Subpart A of 10 CFR Part 51 [3].

The NRC has developed several documents to aid in effective and efficient evaluation of license renewal applications (LRAs). The Generic Aging Lessons Learned (GALL) Report (NUREG-1801) [4] provides generic evaluations of materials and environments to identify applicable aging effects and aging mechanisms, along with acceptable aging management approaches (e.g., AMPs). Use of the GALL Report by applicants and NRC staff facilitates NRC review of LRAs and provides for a stable review process, subject to findings such as emergent technical issues.

The "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants," or SRP-LR (NUREG-1800) [5], provides guidance to the NRC staff reviewers in performing safety reviews of applications to renew nuclear power plant licenses in accordance with 10 CFR Part 54. The SRP-LR was developed to assure quality and uniformity of staff reviews and to present a well defined technical basis from which to evaluate a licensee's application. Availability of the SRP-LR aids in the transparency of NRC staff reviews of LRAs such that applicants can understand the types and detail of information needed by the staff in its reviews. The SRP-LR incorporates by reference the GALL Report.

Both the SRP-LR and the GALL Report were initially issued in 2001 and the last revision, Revision 2, was issued in 2011. Subsequent changes to both the SRP-LR and the GALL Report have been implemented through the License Renewal Interim Staff Guidance (LR-ISG) process, wherein incremental changes are made to these documents. A total of 10 LR-ISGs have been issued for Revision 2 of these documents, as listed on the NRC website.

It should be noted that further full revisions of the SRP-LR and the GALL Report, e.g., Revision 3, will not be issued because of the limited number of plants that would use these reports.

A more detailed description of the license renewal process is provided in TECDOC-1736 [6].

4. Assuring Plant Safety from 40 to 60 Years - Subsequent License Renewal

With the maturity of license renewal, utilities have expressed an interest in renewing their licenses for an additional 20 years. This is called "subsequent license renewal," or SLR, consistent with the terminology of 10 CFR 54.31(d). The Commission has stated that the license renewal rule has provided an effective basis for ensuring safe operation during the license renewal period and will continue to be an effective basis for SLR. Thus the process for SLR is the same as that for license renewal. Consistent with the license renewal rule, the focus

of SLR is on the adequacy of additional aging management activities to ensure safe plant operation during the subsequent period of extended operation.

To support SLR, the NRC has developed guidance documents analogous to those for license renewal, although they specifically address operating conditions to 80 years. The "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report" (NUREG-2191) [7] provides acceptable methods to manage aging effects for 80 years of plant operation. The "Standard Review Plan for Review of Subsequent License Renewal Applications for Nuclear Power Plants" (SRP-SLR) (NUREG-2192) [8] provides guidance to NRC staff reviewers to perform safety reviews of SLR applications.

Revisions of the license renewal guidance documents have focused on operating experience, specifically the lessons learned and findings from these events. Because plants have operated for less than 50 years, other information beyond an exclusive reliance on operating experience was used to identify and address the aging concerns for the operating period up to 80 years.

In 2014, the NRC Office of Nuclear Regulatory Research, in collaboration with the U.S. Department of Energy, published the five volume "Expanded Materials Degradation Assessment," known as the EMDA [9]. This study covered 80 years of operation and systems, structures, and components, including core internals, piping systems, the reactor pressure vessel (RPV), electrical cables, and concrete and civil structures. The EMDA used the phenomena identification and ranking table, the PIRT approach, wherein an expert panel is convened to rank potential degradation scenarios according to their judgment of susceptibility and current state of knowledge.

At the invitation of Constellation Energy and Duke Energy, NRC staff conducted "AMP Effectiveness Audits" at three plants that were operating in their period of extended operation. The purpose of these information collection audits was to understand how their AMPs have been implemented and how effective their AMPs were in identifying aging and unexpected aging phenomena. The findings from these audits were used with information from other sources to inform the AMPs for subsequent license renewal.

The staff also searched international and national operating experience databases for age-related operating experience since the last revision of the license renewal guidance in 2011. In addition, comments from stakeholders were collected during public meetings and a public comment period, as well as comments from the staff.

To develop the SLR guidance document, the NRC created ninety-seven internal expert panels to review and disposition the comments and issues. These panels started with the Revision 2 versions of the GALL Report and the SRP-LR that were developed for license renewal. The panels then reviewed and deliberated on the information provided by the sources identified above. Draft SLR guidance documents (the GALL-SLR Report and the SRP-SLR) were then made available for public comment. Subsequently, the staff held public meetings to provide interested stakeholders information on the disposition of the expert panels and to solicit stakeholder comments. The SRP-SLR and GALL-SLR Report were issued as final documents in July 2017.

5. Status of License Renewal and Subsequent License Renewal

As of the September 2017, licenses have been renewed for a total of 89 nuclear power plant units in the U.S., with 86 units out of a population of 99 units operating with renewed licenses. An additional 7 units have applications under review and 4 units have stated an

intent to apply for license renewal between 2020 and 2022. Forty-seven units will be in the operating period beyond 40 years by the end of 2017.

The U.S. nuclear industry has expressed intent to apply for subsequent license renewal, to enable plant operation to 80 years. These include one application by the end of 2017, and one application each in 2018 and 2019.

6. Technical Issues for Subsequent License Renewal

Based on various workshops, evaluations and public discussion, there has been a consensus that the top four technical issues to provide assurance of safe operation of nuclear power plants for operation from 60 to 80 years are:

- Neutron embrittlement of the reactor pressure vessel
  - Confirm predictive methods using operating experience and
  - Assess embrittlement at higher fluence levels
- Stress corrosion cracking and other types of degradation of reactor pressure vessel internals
  - Evaluate impacts of irradiation assisted stress corrosion cracking, loss of fracture toughness, and void swelling
  - Test materials at higher fluence levels
- Concrete and containment degradation to
  - Evaluate effects of alkali-silica reaction on structural performance of concrete
  - Confirm structural integrity for susceptible plant configurations
- Electrical cable qualification and condition monitoring to
  - Evaluate effects of gamma radiation and thermal exposure in low voltage cables
  - Confirm assessment of medium voltage cable submergence qualification

It is industry's responsibility to develop the technical basis for long-term operation. Lacking resolution of these issues on a generic basis, the first SLR applications will need to address each of these issues on a plant-specific basis as necessary. Once generic resolutions of these topics are identified, the NRC will implement the technical resolutions into the SLR process.

The NRC Office of Nuclear Regulatory Research is collaborating on research activities to address these topics with both domestic industry organizations (i.e., Electric Power Research Institute (EPRI), Nuclear Energy Institute (NEI)) as well as international partners.

7. Conclusions

The NRC's License Renewal Program has successfully evaluated and renewed licenses for more than 80% of the fleet of operating nuclear power plants in the United States. These reviews have focused on ensuring that licensees have adequate aging management in place to ensure safe plant operation during the period of extended operation to 60 years. The limited focus review of license renewal is supported by many other activities in the NRC's on-going regulatory process, including some essential elements identified previously.

With the development of guidance documents for subsequent license renewal, the U. S. Nuclear Regulatory Commission is positioned to review SLR applications, subject to plant-specific consideration of certain technical issues. In conjunctions with the on-going regulatory process, this will ensure safe plant during the subsequent period of extended operation, out to a possible 80 years of operating time.

References

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