UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

December 14, 2018

The Honorable Kristine L. Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SEABROOK STATION UNIT 1 LICENSE RENEWAL APPLICATION: REVIEW OF LICENSEE PROGRAM ADDRESSING ALKALI-SILICA REACTION

Dear Chairman Svinicki,

During the 659th meeting of the Advisory Committee on Reactor Safeguards (ACRS), December 6-7, 2018, we completed our review of the license renewal application (LRA) for the Seabrook Station, Unit 1 (Seabrook) submitted by NextEra Energy Seabrook, LLC (NextEra). Our review considered NextEra's actions to address a concrete degradation mechanism observed in plant structures, known as alkali-silica reaction (ASR). Degradation typical of ASR was first detected at the plant in 2009, and confirmed by concrete borings withdrawn from Seabrook structures in 2010. Since that time, NextEra has undertaken substantial and thorough actions to identify, understand, and address this condition. In August 2016, NextEra submitted License Amendment Request (LAR) 16-03 to revise the Seabrook current licensing basis to adopt a methodology for the analysis of Seismic Category I structures with concrete affected by ASR.

To conduct a focused review of past, current, and future actions to address ASR at Seabrook, our Plant License Renewal Subcommittee met with the NRC staff, NextEra and their consultants on October 31, 2018, separately from our general Seabrook license renewal subcommittee meeting. We also had the benefit of the referenced documents. This letter summarizes that review.

CONCLUSIONS

1. NextEra License Amendment Request 16-03 establishes a robust analytical methodology, supported by a comprehensive large scale test program, for the treatment and monitoring of alkali-silica reaction-affected Seismic Category I structures at Seabrook.

2. The NextEra license renewal application includes two new Aging Management Programs to monitor alkali-silica reaction and building deformation. These incorporate the test program results and license amendment request methodology and assure that the effects of alkali-silica reaction will be effectively tracked and evaluated through the end of the license renewal application period of extended operation.

3. The staff safety evaluations of the license amendment request and alkali-silica reaction-related Aging Management Programs in the license renewal application provide thorough assessments and findings. We agree with the staff's conclusion that NextEra's programs are acceptable.

BACKGROUND

Alkali-silica reaction occurs in concrete, in the presence of moisture, when reactive silica in the concrete aggregate reacts with alkali ions in the pore solution. The reaction produces an alkali-silica gel that expands in volume as it absorbs moisture, resulting in cracking of the concrete and potentially reducing the capacity of concrete structures. The ASR discovered at Seabrook is a slowly developing phenomenon that was initially manifested as micro-cracking and staining of concrete structures. In this instance, its presence is the result of moisture combined with chemically reactive aggregate used in plant construction that was mined from a quarry approximately 150 miles from the site. Based on data and testing performed on the Seabrook concrete, it is reasonable to assume that the ASR phenomenon has been occurring since early operation of the plant (although virtually undetectable in its early stages) and will continue to occur through the balance of plant life.

Because ASR affects concrete properties and imposes structural loadings that were not originally addressed in Seabrook's operating license basis assessments, NextEra submitted LAR 16-03 to revise the Seabrook Updated Final Safety Analysis Report to include methods for analyzing Seismic Category I concrete structures affected by ASR. The LAR is based on testing and analyses that established appropriate concrete properties and analytical methods to demonstrate the acceptability of structures considering the effects of ASR. The LAR methodology has been used to analyze all Seismic Category I structures at Seabrook in their current, ASR-degraded condition, as well as to develop plant specific Aging Management Programs (AMPs) in the LRA to demonstrate that the structures affected by ASR will be acceptable for the proposed period of extended operation (PEO). The staff has completed their reviews of the LAR and ASR-related AMPs in the LRA, and documented their findings in its safety evaluations. We examine each of these topics further in the subsequent sections.

DISCUSSION

Large Scale Testing Program

At the time of initial discovery of ASR at Seabrook, limited data were available addressing ASR in highly constrained (reinforced) concrete such as that used in Seabrook Seismic Category I structures. These structures employ tightly spaced, two-dimensional reinforcing grids that restrict the ability of the concrete to expand in the plane of the grids. NextEra thus conducted a multi-year, large scale testing program (LSTP) at the University of Texas Ferguson Structural Engineering Laboratory. This program determined that, although ASR causes significant degradation of concrete strength properties as measured by standard core samples removed from ASR-degraded structures, the highly reinforced structures themselves did not experience an associated reduction in structural capacity. In fact, the presence of ASR actually increased the load-carrying capacity of such structures. This was a highly repeatable phenomenon, observed through numerous tests on large-scale specimens, fabricated with concrete intentionally subjected to accelerated ASR, well beyond the levels observed to date at Seabrook. Testing included shear capacity tests, reinforcement anchorage and beam flexure tests, as well as concrete anchor pullout tests in ASR-affected concrete.

The LSTP test samples were highly representative of the ASR-affected structures at Seabrook. They incorporated prototypical characteristics for structural dimensions, reinforcing bar sizes and spacing, concrete aggregate, unreinforced concrete cover, and concrete compressive strength prior to ASR. Sodium hydroxide was added to the test sample concrete mixtures to accelerate ASR, which, in conjunction with environmentally controlled aging, enabled the samples to exceed projected plant-level ASR expansion (including the LRA PEO) in a comparatively short timeframe.

ASR Analysis Methodology

In August 2016, NextEra submitted LAR 16-03 to revise the Seabrook current licensing basis to adopt a methodology for the analysis of Seismic Category I structures with concrete affected by ASR. The LSTP results were used to develop a set of analysis guidelines to address ASR in a manner consistent with the original industry standard codes used in design and construction of these structures at Seabrook (ASME Section III and ACI 318-71).

Notably, the revised analysis guidelines specify that original (non-ASR-degraded) concrete material strength properties be used in the analyses. Although the LSTP results described above demonstrated that ASR enhanced the structural capacity measurements, ASR also increases demand on the structures, in the form of increased compressive stresses in the concrete and increased tensile loads in the steel reinforcing members, due to volumetric expansion of the concrete. Methods for incorporating these new loadings, using appropriate load factors, are addressed in the LAR.

NextEra also commissioned detailed reanalysis of all ASR-affected Seismic Category I structures, as well as the intake and discharge structures, adding ASR loading to existing design basis loads, in accordance with the LAR methodology. This methodology will also be used to establish building-specific, acceptable margins and building deformations as ASR progresses during the PEO.

Augmented Structural Monitoring Program

The LSTP also included tests to define instrumentation and measurement techniques that can be used to monitor current and future development of ASR. The testing determined that ASR expansion in the plane of the reinforcing grids (in-plane expansion) saturates at a relatively low strain level, after which the expansion is constrained by the reinforcement. Subsequent expansion then occurs transverse to the reinforcing grids (out-of-plane expansion). The testing identified different measurement techniques for monitoring these two modes of ASR expansion. The test program and analyses determined that in-plane expansion can be effectively monitored using a method of crack width monitoring within defined grid patterns on the concrete surfaces (combined cracking index or CCI). After the in-plane expansion saturates, subsequent out-of-plane expansion will be characterized using a specially developed snap ring borehole extensometer. The LSTP defined the accuracy and limitations of these two measurement techniques, which have been incorporated into structural monitoring AMPs for ASR at Seabrook. An ASR monitoring AMP defines measurement locations, measurement time intervals, and ASR expansion limits beyond which corrective action is required.

A second new AMP establishes a building deformation monitoring program to monitor gross building deformation as the result of ASR and compare it to acceptable limits. Predicted building deformations from these analyses are compared to periodic measurements to evaluate their accuracy and to ensure that building deformations do not exceed acceptable margins. The monitoring program also ensures that required building-to-building seismic gaps and seal dimensions are maintained, and that relative building deformations do not damage interconnecting piping and other equipment.

Independent ASR Research

As previously noted, at the time of initial ASR observation at Seabrook in 2009, there were limited data available on the effects of ASR on highly constrained structures. However, in the interim, a large body of ASR research similar to the LSTP is ongoing, including domestic research sponsored by the NRC's Office of Nuclear Regulatory Research at the National Institute of Standards, as well as large Canadian and European programs. These programs have produced similar results to the LSTP, observing increased structural capacity in highly-constrained, ASR-affected structures. Also noteworthy is the fact that the National Institute of Standards program (and others) chose a similar approach of fabricating prototypical, structural-sized test samples, with concrete produced to artificially accelerate ASR.

Staff Reviews

The staff has dedicated continuous regulatory oversight to the licensee programs addressing ASR issues at Seabrook, from initial and continued operability determinations with the ASR condition to review and approval of the AMPs for structural and building deformation monitoring. Since the initial observation of ASR at Seabrook, the staff has maintained a strong, augmented program of inspection and audits to identify plant condition changes due to ASR, as well as structures and equipment functions that may be affected by such conditions. Several important ASR-related conditions were identified by staff auditors or regional inspectors, either as a direct result of walkdowns or by their detailed reviews of corrective actions, licensee condition reports, and program bases documents. These included:

- Groundwater infiltration as a potential cause of accelerated degradation of plant concrete and steel support structures

- Water leakage from the spent fuel pool fuel transfer canal

- Structure or building deformation caused by widespread ASR expansion

The slow progression of the ASR conditions at Seabrook allowed NextEra to develop appropriate experimental and analytical approaches to derive better understanding and predictive capability of ASR impacts via their LSTP. The staff's review and audit process for this test program confirmed that the research, testing, analyses, and application of results met industry quality standards and NRC regulatory requirements. In parallel, the staff established frequent, periodic audits and team reviews of each of the ASR-related response programs at the site. The reviews demonstrated that the NextEra organization was fully prepared to implement and execute these programs.

The staff's review process for the NextEra LSTP, LAR, and ASR programs in the LRA has been deliberate and comprehensive, and it included effective use of requests for additional information to identify and resolve critical issues. This has resulted in robust analytical procedures and AMPs that are well documented in the final NextEra LAR and LRA submittals. The staff's LAR and LRA safety evaluations and their referenced reports document their audits and reviews and provide thorough assessments of the NextEra programs designed to assure proper identification, monitoring, and evaluation of ASR-related conditions at Seabrook. The staff assessments conclude that these programs will effectively identify and characterize the ASR condition and are capable of evaluating its impact on the ability of the affected structures to accomplish their design basis functions.

SUMMARY

NextEra has undertaken comprehensive actions to characterize, evaluate, and apply test results into Seabrook-specific analysis and monitoring programs to understand current building structural capacity and to monitor and evaluate future building performance. The staff has conducted assessments of the testing program, the data from the testing, and the efficacy of licensee employment of these programs as bases for judging the acceptability of the affected structures for present and extended life through the PEO. We concur with the staff conclusion that, while some of the structures are degraded, they are fully capable of performing their credited function through the requested PEO under the committed enhanced monitoring and evaluations.

Sincerely,

/RA/

Michael Corradini,
Chairman

REFERENCES

1. NextEra Energy Seabrook LLC, “Seabrook Station License Renewal Application,” May 25, 2010 (ML101590098, ML101590101, ML101590091).

2. NextEra Energy Seabrook LLC, License Amendment Request 16-03, “Revise Current Licensing Basis to Adopt a Methodology for the Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction,” August 1, 2016 (ML16216A240).

3. NextEra Energy Seabrook LLC, “Non-Proprietary Version of Enclosure 1 to SBK -L-17156,” October 17, 2017 (ML17291B136).

4. U.S. Nuclear Regulatory Commission, “Safety Evaluation Report Related to the License Renewal of the Seabrook Station,” September 28, 2018 (ML18254A294).

5. U.S. Nuclear Regulatory Commission, “Seabrook Station, Unit No. 1 – Follow-Up of Alkali Silica Reaction Open Item License Renewal Inspection Report 05000443/2018011,” August 10, 2018 (ML18222A292).

6. NextEra Energy Seabrook LLC, “Seabrook Station Updated Final Safety Analysis Report,” Revision 18, October 27, 2017 (ML17310A361).

7. U.S. Nuclear Regulatory Commission, “Seabrook Station, Unit No. 1 – Site Visit Report Regarding Regulatory Audit for License Amendment Request RE: Alkali Silica Reaction License Amendment Request (CAC No. MF8260),” July 26, 2017 (ML17199T383).

8. U.S. Nuclear Regulatory Commission, “Alkali Silica Reaction Monitoring Aging Management Program Audit Report Regarding Seabrook Station, Unit 1 License Renewal Application Review (CAC NO. ME4028),” December 21, 2016 (ML16333A247).

9. U.S. Nuclear Regulatory Commission, “Regulatory Audit Plan – Alkali Silica Reaction Aging Management Program, Regarding Seabrook Station, Unit 1 License Renewal Application Review (CAC NO. ME4028),” October 13, 2016 (ML16277A549).

10. U.S. Nuclear Regulatory Commission, “Seabrook ASR-Monitoring Program Audit Report,” October 29, 2015 (ML15337A047).

11. U.S. Nuclear Regulatory Commission, “Seabrook Station, Unit No. 1 – NRC Integrated Inspection Report 05000443/2014003,” August 5, 2014 (ML14212A458).

12. U.S. Nuclear Regulatory Commission, “Aging Management Program Audit Report Regarding the Seabrook Station License Renewal Application (TAC Number ME4028),” December 23, 2013 (ML13354B785).

13. U.S. Nuclear Regulatory Commission, “NextEra Energy Seabrook - NRC License Renewal Inspection Report 05000443/2011007,” May 23, 2011 (ML111360432).

14. U.S. Nuclear Regulatory Commission, “Audit Report Regarding the Seabrook Station License Renewal Application (TAC Number ME4028),” March 21, 2011 (ML110280424).

15. U.S. Nuclear Regulatory Commission, “Scoping and Screening Audit Report Regarding the Seabrook Station,” February 4, 2011 (ML110270026).

16. U.S. Nuclear Regulatory Commission, NUREG-1801, “Generic Aging Lessons Learned (GALL) Report,” Revision 2, December 2010 (ML103490041).

17. U.S. Nuclear Regulatory Commission, NUREG-1800, “Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants,” Revision 2, December 2010 (ML103490036).

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