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November 4, 2013

Allison M. Macfarlane, Chair
Kristine L. Svinicki, Commissioner
George Apostolakis, Commissioner
William D. Magwood, IV, Commissioner
William C. Ostendorff, Commissioner
U.S. Nuclear Regulatory Commission

Mail Stop O-16G4
Washington, DC 20555-0001

Dear Commissioners,

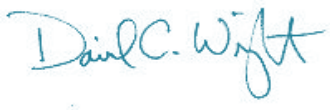
Please find below analysis and commentary by Dr. Paul Brown, Professor of Ceramic Sciences and Engineering, Penn State University, prepared under contract to the Union of Concerned Scientists (UCS).

Dr. Brown's commentary addresses ASR concrete degradation at the Seabrook nuclear power plant and specifically reviews the NRC's inspection report O5OOO443/2012010 (ML 13221A172) concerning the NRC's Confirmatory Action Letter to NextEra Seabrook Energy, LLC dated August 9, 2013.

I have also attached a summary document prepared by the Union of Concerned Scientists and the Newburyport, MA-based C-10 Research & Education Foundation detailing the two organization's concerns and recommendations with regard to the testing, management and mitigation of the ASR concrete degradation at Seabrook.

UCS respectfully requests a detailed response in writing from the NRC to the concerns and recommendations outlined in Dr. Brown's analysis and the UCS/C-10 summary document. We request that you incorporate in your response the actions your agency will take to correct the deficiencies we have identified in NextEra's ASR concrete degradation investigation.

Sincerely,



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Cc: William M. Dean, Regional Administrator Region One, United States Nuclear Regulatory Commission

Mel Gray, Branch Chief, Engineering Branch One, United States Nuclear Regulatory Commission

Commentary on

SEABROOK STATION, UNIT NO. 1
- CONFIRMATORY ACTION LETTER FOLLOW-UP INSPECTION
- NRC INSPECTION REPORT O5OOO443/2012010 (ML 13221A172)

Paul Brown, Ph.D.[1]
September 29, 2013

Background to the Commentary

The occurrence of the alkali silica reaction (ASR) has been discovered in the concrete at the Seabrook Nuclear Power Generating Station. ASR is an expansive chemical reaction that occurs within concrete and causes the concrete to expand and crack.

On May 16, 2012, the Nuclear Regulatory Commission (NRC) sent NextEra, which owns Seabrook, a Confirmatory Action Letter (CAL) documenting 11 actions NextEra committed to undertake in response to the discovery of ASR at the plant. The Commentary below is in response to the NRC's August 9, 2013 inspection report that follows up on actions in the Seabrook CAL.

When the NRC decides that one of the actions specified in the CAL has been adequately completed, that CAL item is said to be "closed." This Commentary addresses the closure of several CALs at Seabrook, among other things.

While the origin of ASR and its effects on concrete are well understood, there is uncertainty with respect to its effects when the concrete is highly reinforced. Although the presence of internal steel reinforcement is anticipated to resist the growth in the width of cracks in the material, its presence will not limit the progression of the ASR itself. This situation can make it difficult to establish a means for benchmarking the progression of the reaction and the associated damage to the concrete unless concrete samples are extracted from the affected structures and tested.

1) The first area of concern is that NextEra has preferred to use measurements of crack widening (*combined crack indexing*, or CCI) of concrete structures at Seabrook as the primary criterion for establishing the progression of ASR. This is of concern because there is not a well-established basis for relying on this criterion as a reliable measure of damage in highly reinforced concrete.

2) A second area of concern is the lack of predictive capability of CCI measurements when attempting to establish when the concrete in a structure will become incompetent from the point of view of engineering design.

3) A third area of concern is that there is presently no generally accepted technology to mitigate the effects of ASR within an existing concrete structure.

[1] Dr. Brown is an ASR concrete expert at Penn State University who has worked for the National Institute of Standards and Technology (NIST) in Gaithersburg, MD and has advised the NRC. He was a contributor to the newly released report *Codes and Standards for Nuclear Plant Concrete for Nuclear Power Plants*, and is serving on an American Concrete Institute (ACI) ASR Task Group.

Based on these concerns there has been an ongoing interaction between the NRC and NextEra to address these issues. Unfortunately, a number of the documents pertinent to this dialog have not been made available for public commentary.

In the Commentary below:

- Text in Times New Roman font is my commentary on the Aug. 9 NRC inspection report. The numbering below follows the section numbers in the inspection report.

- Text in Arial font is quoted from the Aug. 9 NRC inspection report.

Commentary:

1.0: The NRC report references document FP 100716 in which NextEra cites the lower bound values for structural capacity. It is not clear whether this is the present lower bound attributed to in-place concrete. If so, it is appropriate to state what this is and how it was established. It is reasonable to anticipate that the ultimate lower bound of the structural capacity of the ASR-affected concrete in compression and tension will be that associated with the frictional forces between unbonded aggregate. The Seabrook concrete structures contain lap splices between the embedded reinforcement. A lap slice is formed when sections of rebar are laid parallel to one another but are not physically connected. The theory is that the concrete between the adjacent sections of rebar is strong enough to transfer stresses between them. This ability is reduced when the properties of the concrete are affected. Although NextEra has claimed that concrete properties are not important in and of themselves, this is not true for these situations in particular. **This lower bound would have a significant impact on the integrity of lap splices and anchorage capacity in particular**.

3.0: The NRC report refers to CAL-2, and notes that NextEra summarized two root causes:

> RC1 - The ASR developed because the concrete mix designs unknowingly utilized an aggregate that was susceptible to Alkali-Silica Reaction. Although the testing was conducted in accordance with ASTM standards, those testing standards were subsequently identified as limited in their ability to predict long term ASR.
>
> RC2 - The health monitoring program for systems and structures does not contain a process for periodic reassessment of failure modes that were excluded from the monitoring criteria to ensure that the monitoring/mitigating strategies remain applicable and effective.
>
> Based upon the team's initial review, the inspectors concluded that the second root cause identified was not sufficiently characterized in NextEra's May 24, 2012, submittal. Specifically, NextEra did not clearly describe the performance and organizational factors that contributed to inadequacies in the Structures Monitoring Program (SMP) and the failure of the Seabrook staff to have identified ASR degradation of reinforced concrete structures sooner.

The above statement seems inconsistent with the closure of CAL-2. It i**s** well understood that the occurrence of cracking in a concrete structure, regardless of its genesis, renders that structure susceptible to other forms of deterioration. No systematic analyses appear to have been done on the Seabrook concrete structures to establish the presence or absence of corrosion of embedded steel as a baseline for extrapolating future performance. This seems particularly relevant considering that there is an unresolved issue of potentially aggressive water migration through the concrete via unknown paths.

4.0: The NRC report cites the June 8, 2012 NextEra Corrective Action Plan (CAP) (and May 1, 2013 update (Enclosure 2)) as satisfying CAL-4 by outlining "the major elements of diagnosis, evaluation, prognosis and mitigation of ASR-affected structures."

> The team identified no findings. Based upon the team's review, CAL ltem 4 is closed.
>
> NextEra's ASR project staff stated that they plan to maintain the ASR Project CAP as a "living document" and will update it periodically to capture completion of activities and add new actions, as appropriate.

The above statement seems inconsistent with the closure of CAL-4.

5.0: CAL-7 was a NextEra commitment to do prism testing to assess long-term aggregate expansion. However, because the mortar bar test results showed that there was sufficient reactive aggregate to support the continued occurrence of ASR, this test was dropped.

6.0: CAL-8 called for submitting technical details for proposed large-scale testing. This testing is being carried out at the University of Texas (UT) at Austin. Testing has not yet gotten far enough along to provide results. The theoretical basis for the testing is to evaluate ASR-susceptible concrete that is reinforced in two dimensions but not in the third as a model for concrete in the Seabrook structures where similar reinforcement architecture was used. **This type of reinforcement is found in the majority of the Seabrook structures**.

CAL-8 cites back to NextEra's updated Corrective Action Plan of May 1, 2013, which is a document 104 pages in length that lays out, with milestones, the testing protocols being carried out to evaluate ASR at Seabrook.

> No findings were identified. Based upon team review of the submitted testing program documents and related inspection activities, the team concluded that NextEra has provided an appropriate level of detail of the proposed large-scale specimen testing program, and CAL ltem 8 is closed.

7.0: CAL-9 is related to a monitoring program.

> Based in part on NRC observations, NextEra issued Revision 3 to the SMP on April 30, 2013. The SMP enhancements are: 1) the addition of periodic (every 30 months) combined crack indexing (CCl) measurements at 72 discrete locations identified as Tier ll (Acceptable with Deficiency) areas (CCl values between 0.5 mm/m and 1.0 mm/m, or crack widths greater than 0,2 mm, but less than 1.0 mm) to collect quantitative information on the progression of ASR expansion/degradation (this monitoring was being performed, but not documented in the SMP); and, 2) inclusion of the periodic groundwater sampling program for monitoring of chemical attributes detrimental to concrete structures.

Based on the prior discussion, the value of this program is questionable considering the criteria being applied to what is an acceptable crack. **New cracks of any size should not be forming in such mature concrete structures, regardless of displacement. There is no existing standard that correlates crack displacement in a reinforced structure to the extent of ongoing ASR within that structure.**

Consequently it is a goal of the work at UT-Austin to establish such a correlation:

> The crack growth monitoring provides a visual indication of the progression of ASR within a reinforced concrete structure, The relative width and number of visible cracks may be correlated to the overall progression of ASR and may be used to evaluate ASR impact on structural performance. However, ASR cracking and crack propagation is closely associated with the specific reinforcement design and structural loading. Accordingly, the adequacy of CCI measurement as a long-term structures-monitoring methodology for Seabrook structures is being further evaluated by NextEra as part of the UT-Austin FSEL testing program. The results of the UT-Austin testing program are intended to be used to validate this methodology for application at Seabrook.

NextEra has committed to monitor the ground water chemistry. However, **the present report does not provide any detail as to this program.**

8.0: Regarding CAL-11. NextEra has committed to continue a program of the anchorage capacity of ASR-affected concrete. However, **the present report does not provide any detail as to this program.**

The testing program at UT-Austin will also evaluate the variations in the strength and moduli values of test blocks and cylinders. However, **the present report does not provide any detail as to this program.**

9.0: Previously Identified Issues of Interest

9.1: NextEra identified 26 locations where crack displacement in Seabrook concrete (including the containment structures) have become excessive. This finding requires a detailed structural assessment. However, the **present report does not provide the criterion for defining what constitutes an excessive crack, nor does it provide any detail as to this program.**

> The [NRC inspection] team found [NextEra's] approach of reducing load factors to establish more representative demand loads in order to demonstrate additional margin to assure structural integrity acceptable for the current state of ASR degradation. NextEra plans to credit the load factors in the load demand calculation to establish full qualification per the Final Safety Evaluation Report (FSAR) licensing basis in the final operability determination, following completion of the testing program at UT-Austin.

It is not entirely clear what the forgoing actually means.

For those areas where cracks exceeded 1.5 mm/m, NRC found that the NextEra structural analyses was not adequate and has requested that additional analyses be carried out.

9.2: NextEra is maintaining the position that materials property testing need not be carried out:

> For the long-term, NextEra has elected to evaluate structural performance (operability) of the Seabrook ASR-affected reinforced concrete structures by developing a testing program involving large specimens that are fabricated to closely replicate the Seabrook concrete and reinforcement design. NextEra has pursued this method, instead of conducting detailed material properties

testing of core samples, based upon available laboratory testing and data that indicates that measurable material properties of removed cores do not, under all circumstances, accurately represent the "in situ" mechanical properties of the concrete. The reason for the difference is that prior to removal of the core sample, that concrete specimen is subjected to the specific structural compressive stresses (dead loads, live loads, and hydrostatic loads) and inherent restraint due to reinforcement bars. When removed from the structural member, that concrete specimen is unrestrained. In addition, as identified in the associated core sampling standard (ASTM C42, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete"), core sample test results may be "...affected by many factors such as the strength level of the concrete, the in-place temperature and moisture histories, the degree of consolidation, batch-to-batch variability, the strength-gain characteristics of the concrete, the condition of the coring apparatus, and the care used in removing cores."

It is well understood that drilled cores are extracted from an existing structure and have been subjected to the service environment associated with that structure. This in no way invalidates the result of the testing. The NextEra preposition misuses the cautionary language of ASTM C42 and appears to be an attempt to avoid accumulating data which might be regarded as problematic.

NextEra has committed to extract and test additional cores. However, the **present report does not provide any detail as to this program.**

9.3: This section states that ASR causes chemical prestressing. Such a statement indicates a misunderstanding of prestressing. In prestressing, steel reinforcement is placed in tension prior to concrete placement. When the tension is removed the steel places the concrete in compression to reduce cracking. This is remote from the conditions within ASR-affected concrete.

The present report indicates an assessment of the extent of stress presently affecting the reinforcement and cites that the steel is not being plastically deformed.

9.4: No evidence of rebar corrosion has been found.

9.5: The large-scale testing program is designed to establish the probability of mid-wall cracking that is not amendable to being detected by inspections of surface cracks. However, **this assessment should also be carried out on the actual in-place concrete.**

9.6: This section indicates that NRC staff finds the use of the CCI as an acceptable method of conditional assessment. This is unfortunate because it does not encourage NextEra to apply NDE techniques or other (assessment) techniques to quantify conditional analyses.

The CCI index indicates continued ASR-induced expansion to be occurring in the Seabrook concrete.

ln the ASR Crack Index Report (FP10081 1), NextEra measured CCI values for 26 locations in the monitoring program and compared the results to the data taken in June 2012. The December CCI data shows an apparent increase in most (19 of 26) of the monitored locations. NextEra concluded the apparent increase in CCI values may be due to seasonal temperature variations because the concrete (in December) was significantly colder, which may cause the concrete to contract between the cracks, increasing the apparent crack widths,

This assumption is unfounded. If the physical dimensions of a structure containing cracks are decreasing, the crack displacements will also decrease.

The inconsistencies between pin expansion data and the CCI data show the complexity of interpreting the results of the analyses being conducted.

12: Based on a NextEra assumption that ASR would only be limited to below grade concrete, an aircraft impact analysis was done. The assumption that ASR will be limited to below grade concrete is unfounded. **The assumption that aircraft impact will not transfer stresses to ASR compromised concrete is unfounded.**

Prepared under contract with the Union of Concerned Scientists