Comments by WJR on Draft TIA for ASR at Seabrook

PRELIMINARY DRAFT RESPONSE TO REQUEST FOR TECHNICAL ASSISTANCE FOR SEABROOK STATION ALKALI-SILICA REACTION DEGRADATION OF CONCRETE

(PREDECISIONAL – OFFICIAL USE ONLY
FOR INTERNAL BRAINSTORMING & COMMENT)

1.0 INTRODUCTION

By letter dated September 12, 2011 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML1116105300), the U.S. Nuclear Regulatory Commission (NRC) Region I Office requested technical assistance from the Office of Nuclear Reactor Regulation (NRR) to evaluate the potential consequence of alkali-silica reaction (ASR) degradation of a safety-related concrete structure at Seabrook Station. More specifically, based on NRR review for adequacy of a NextEra prompt operability determination (POD) and its associated open issues, NRC staff should be able to identify what additional information is needed in order to fully evaluate the impact of the degradation on the current licensing and design basis in the final operability determination for structures important-to-safety at the plant. As the primary case for review, NextEra evaluated the Seabrook Control Building ("B" Electrical Tunnel and Penetration Room) in light of the recently discovered degradation mechanism. Other structures important-to-safety within the scope of the maintenance rule have also been affected by the ASR problem.

Region I requested NRR assistance to address the above concerns by providing answers to the five Task Interface Agreement (TIA) questions which are stated in Section 3.0 "Evaluation" of this response.

2.0 BACKGROUND

NextEra Energy (the licensee) analyzed concrete core samples from the interior surface of exterior walls of the Control Building as part of their assessment to support renewal of their license. In August 2010, tests undertaken as a part of the core sample analysis reported a change in material properties. The analysis reported the presence of ASR-degradation in core samples taken from chronically wet walls below grade, with reductions reported in the concrete compressive strength and modulus of elasticity from that expected. NextEra evaluated these parametric reductions to determine the impact on the design basis of the Control Building. By their process, the licensee performed an immediate and prompt operability determination (POD) and concluded, preliminarily, that the Control Building (CB) was operable but with reduced strength reserves to design capacity.

NextEra continued to evaluate the extent of this condition for five other safety related concrete buildings. The other five buildings for which concrete core samples were taken were: Equipment Vault (housing ECCS equipment including that for Residual Heat Removal (RHR)], Radiological Controls Area (RCA) Walkway, Emergency Feedwater Building (EFW), Emergency Diesel Generator (EDG) Building, and the Containment Enclosure Building (CEB). As of June 30, 2011 there are two open prompt operability determinations, one for the Control Building and one for the other five buildings collectively. The licensee found additional evidence of ASR in four of the five other buildings and they evaluated that information in a separate immediate and prompt

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operability determination using the same evaluation techniques as for the Control Building. This evaluation is also considered preliminary or open. Based on NRC internal discussions, it appears that the calculation methods and correlations that NextEra used in their prompt operability determination may not be fully appropriate in light of the ASR problem.

NextEra's planned actions are two-fold: 1) to follow their operability determination process; and, 2) to follow the guidance in NEI 95-10, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 – The License Renewal Rule," to develop an aging management program to support the license renewal application. Possible outcomes to the PODs are: 1) restored conditions (which may not be possible); 2) resolved conditions (use "as is" by procedure change incorporated or Action Request (AR) disposition approved); or 3) current licensing basis (CLB) revised (e.g., 10 CFR 50.59 evaluation). The licensee has posted on the Certrec internal website their operability determination process for reference (EN-AA-203-1001_005, No. 1 on Certrec Document Tab List).

NextEra's proposal related to license renewal was described in a letter dated April 14, 2011, under the response to NRC request for additional information B.2.1.31-1 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML11108A131). This letter describes periodic reviews for operability as information is developed to support the aging management review. At the time, the proposal included another analysis (termed "final" by NextEra) of the impact of ASR on the current licensing and design basis, including the extent of the condition, to be completed by June 2011. Since that letter and as noted above, the control building POD was kept open; a new immediate and POD were completed for the other five building core sample results that were involved in an extent of conditions review. The subject NextEra letter also commits to an Engineering Evaluation to be completed in March 2012. On June 29, 2011, the NRR Division of License Renewal issued another "Request for Additional Information" (ADAMS Accession No. ML11178A338) related to key aspects of NextEra's comprehensive plan for assessing the ASR problem for the Structures Monitoring Program including that for the Fuel Handling Building and Containment ("Followup RAI B2.1.31-1, B2.1.31-4, and B2.1.28-3). The response to this letter dated August 11, 2011, (ADAMS Accession No. ML112227A0230) does not reflect a comprehensive plan for determining operability/functionality of affected buildings along with plans for the development of aging management review and program.

With respect to Part 50 requirements, Region I reviewed the NextEra current Structures Monitoring Program and found a violation of the maintenance rule for the control building. The finding is described in detail in NRC Inspection Report 05000443/2011002 (ADAMS Accession No. ML111330689). More details related to the newly discovered ASR issue were also documented in the NRC Inspection Report 05000443/2011007 (ADAMS Accession No. ML111360432) as part of a license renewal inspection. The cover letter for the latter report notes that the aging management review for the ASR issue is not complete and that there is a need for a continuing review in the Part 50 and 54 areas. The staff of Region I and NRR (Division of Engineering and Division of License Renewal) have been discussing actions since January 2011 to ensure that the Part 50 and 54 reviews are coordinated.

The documents listed below were made available for review on the licensee's "Certrec" internal website (Certrec Document Library Tab List). These documents reflect current NextEra view of operability for the Control Building and the associated tunnel and penetration room. The

"Certrec" system was set up in order to facilitate NRC staff access to NextEra's internal documents. The NRC staff was requested to inform Region I and NextEra if the document is to be printed, for review purposes, prior to doing so.

1. C-S-1-10159 CALC_000, Rev. 0, 'B' Electrical Tunnel Transverse Shear Evaluation Supplement to Calculation CD-20

2. C-S-1-10150 CALC_000, Rev. 0, Effects of Reduce Modulus of Elasticity – 'B' Electrical Tunnel Exterior Walls

3. CD-20-CALC, UE Control and Diesel Generator Building Design of Material and Walls below grade for Electrical Tunnel and the Control Building (Original Design Calculation)

4. Action Request (AR) 581434 Prompt Operability Determination Reduced Concrete Properties Below Grade in 'B' Electrical Tunnel Exterior Walls.

On April 27, 2011, NRR Division of Engineering provided support by performing an initial review of NextEra's basis for acceptability of the reduction in modulus of elasticity in light of concrete core testing which supported 10 CFR 50.59 screening process without prior NRC staff review and approval. This evaluation and its related design change document accept the reduced parameters of compressive strength and modulus of elasticity for the Control Building and the Containment Enclosure Building as a potential disposition for the operability determination (Certrec Document Library Tab List, Enclosure Bldg and Control Bldg MSP – Design Change Package Description No. EC-272057, Rev. 000, Concrete Modulus of Elasticity Evaluation). The staff questioned the adequacy of this screening action.

The licensee is also planning an apparent cause review for the maintenance rule violation noted above. Corrective actions include a comprehensive walkdown of all structures important-to safety with suspected ASR condition in accordance with a revised structures monitoring program procedure that meets the latest ACI standard in the area (ACI 349.3R-02). This has been completed for the control building, containment enclosure building, and the containment. Completion of these assessments for the other buildings is tentatively December 2011. Further, the licensee plans to conduct a root cause evaluation of the ASR issue which should be completed in time for incorporation into the planned March 2012 Engineering Evaluation as noted above.

<u>Licensee Position</u>

To date, within the limitations of their testing and analysis, NextEra determined that none of the seismic category I structures tested have been found to be outside their design basis and were, therefore, operable with extent of conditions questions needing be addressed. The Seabrook design and licensing basis to which the licensee made these determinations was documented in UFSAR Section 3.8. NextEra is willing to address the additional questions from the NRC staff; but, it is uncertain if those questions will be addressed in the final operability determination tentatively scheduled for September 30, 2011. It also remains uncertain what NextEra's comprehensive plan is based on review of their August 11, 2011, response to NRC letter of June 29, 2011.

In light of the newly discovered ASR issue, it appears that NextEra technical personnel are developing new insights for what key aspects must be addressed in the final operability determination for any building with evidence of ASR. NextEra is considering NRC staff questions to date and has hired consultants in this area. These consultants also will be developing a new model for the Containment Enclosure Building load analysis.

[*It should be noted that NextEra's schedule indicated in the above paragraph has changed and the prompt operability determinations were revised in mid October 2011 for the B Electrical Tunnel (AR 581434, Revision 001) and Containment Enclosure Building, RHR Equipment Vaults, EFW Pump House, and Diesel Generator Fuel Oil Tank Rooms (AR 01664399, Revision 001).*]

Recommended Actions by Region I

In order for Region I to independently determine operability of the control building or any other important-to-safety structure affected by the ASR problem; and, as a primary case, we need a review for adequacy of the control building prompt operability determination and any related open issues as identified by NextEra. This information would be applied to the final operability determination for the control building and any other affected important-to-safety structures. The important-to-safety structures affected by the ASR problem are within the scope of the maintenance rule and are also consistent with in the scope of license renewal. More specifically we need to independently develop a comprehensive set of issues to be applied to any final operability determination as a part of our oversight of the licensee's process and any new insights gained from NextEra's technical research.

Accordingly, Region I requests that NRR evaluate the adequacy of NextEra's control building prompt operability determination and its related open issues with particular focus, but not limited to, the below listed key technical questions. The licensee has provided a set of documents as noted on the "Certrec" website referenced above, but the NRR review should not be limited to those documents. Region I will facilitate ensuring that additional documents, as needed, are available on the website or, as necessary, by an onsite inspection. NRR's determination should enable the staff to confirm that there is reasonable assurance of continued operability given the concrete degradation identified due to ASR for the control building once the final operability determination is made by NextEra for this or any other important structure affected by the ASR problem.

During the course of this review, Region I requests that NRR specifically identify any concerns with the assumptions, methodologies, or calculations, etc., along with the regulatory or other basis of each concern; and, notify Region I immediately if NRR finds that any of the reviewed documents for the control building do not provide reasonable assurance of continued operability of that building. As a minimum, the response to this TIA should include an independently developed comprehensive set of issues to be addressed in the final operability determination for the Control Building in order for us to further assess the licensee's process and their new insights gained for all important-to-safety structures with evidence of ASR.

3.0 EVALUATION

Question 1:

Working with Region I staff in an inspection forum, NRR staff should identify a comprehensive list of issues that need to be addressed in the final operability determination for the Control Building, given the current view of operability by NextEra as reflected in the prompt operability determination.

[Discussion by Region 1: NRC staff identified questions as listed in the NRC RAI [(ADAMS Accession No. ML11178A338) dated June 29, 2011. The questions related to key aspects of NextEra's comprehensive plan for assessing the ASR problem for the Structures Monitoring Program, including that for the Fuel Handling Building and Containment (Followup RAI B2.1.31-1, B2.1.31-4, and B2.1.28-3)]. If the issues are initially considered comprehensive, please give consideration to the below additional views produced by the regional technical staff. If those issues are not considered comprehensive, then identity those additional issues to be included with consideration to those listed below along with regulatory or other basis for the concern. An example would be the need for Poisson ratio calculations or core samples because there are assumed numbers in the UFSAR or the need for stiffness damage tests because of applicable ACI standard requires it in the current licensing basis.]

Response:

The NRR staff notes that reference to the Control Building in TIA 2011-13 refers to the "B" Electrical Tunnel, which runs below the Control Building foundation, extending between EL -20 ft and EL +21 ft 6 in, the vertical walls of which have been reported to be affected by ASR. It is noted that the Control Building structure above grade and its foundation have not been reported to be affected by ASR. This TIA response will hereafter use the designation of "B" Electrical Tunnel rather than Control Building for the ASR affected structure that is the subject of the TIA.

The Electrical Tunnels are Seismic Category 1 reinforced concrete structures designed to house the Train A and Train B safety-related cable/cable-tray systems in train independent structures. The structure protects the safety-related systems, equipment and components located inside the Electrical Tunnels against all postulated external environmental conditions.

The Electrical Tunnels structure is designed to withstand all credible conditions of loading, including normal loads, severe environmental loads, extreme environmental loads, and abnormal loads. The loads included ground water hydrostatic pressure, OBE and SSE loads. The Electrical Tunnels are situated one on top of the other.

There are no defined Technical Specification functions associated with the Electrical Tunnel. It stands to reason that the electrical transmission cables housed within the structure are necessary for operation, safe shutdown, or permit continued decay heat removal. The structural integrity of the structure that houses them is an important function during all modes of operation.

A program to address the diagnosis, prognosis, appraisal and aging management of important-to-safety concrete structures subject to alkali-silica reaction (ASR) degradation should, in

general, consist of the following elements: (i) Condition assessment (extent and characterization); (ii) Root Cause; (iii) Testing to estimate "expansion to date" and "the current expansion rate"; (iv) Testing to estimate "potential for further expansion"; (v) Interim and long term structural appraisal; (vi) Monitoring and aging management; (vii) Mitigative and remedial measures and (ix) Potential for further deterioration due to other mechanisms. In response to the TIA question, the NRR staff provides the following observations and guidance.

(a) During the period 9/26/2011 thru 9/28/2011, NRR staff participated, along with Region 1 inspectors, in an inspection with regard to the ASR issue at Seabrook Station. During the inspection, the NRR staff reviewed the licensee's prompt operability determination (POD) for the B Electrical Tunnel (AR 581434, Revision 000). This POD had concluded that the structure is operable since it is fully qualified, meeting as-built condition. Although there was no immediate safety concern identified, the staff provided the following broad comments with regard to the POD. Similar comments were provided on AR 01664399, Revision 000, which is the POD for other ASR-affected Category 1 structures.

- It is based on the assumption that the relationships (empirical based on sound concrete) in the ACI 318 code for concrete between compressive strength (f'c) and shear strength, tensile strength, bond, modulus of elasticity etc. remains unaffected by ASR.
- Effect of ASR (reduced concrete properties) on the design qualification of anchorages of supports for safety-related components (e.g. cable-trays carrying SR cables, etc) attached to ASR-affected concrete was not addressed quantitatively.
- Effect of ASR on shear capacity of the wall was not addressed quantitively.
- Effect of ASR on natural frequency and global response of the tunnel wall under seismic load and load combinations was not addressed quantitatively.

Based on the feedback the licensee revised its prompt operability determinations in mid October 2011 for the B Electrical Tunnel (AR 581434, Revision 001) and Containment Enclosure Building, RHR Equipment Vaults, EFW Pump House, and Diesel Generator Fuel Oil Tank Rooms (AR 01664399, Revision 001). The determination was revised from "Affected SSC should be considered Operable since it is fully qualified, meeting As-Built condition" to "Affected SSC should be considered Operable but degraded, and below Full Qualification. Continued Operability is based on the provisions of RIS 2005-20." The licensee's conclusion also stated that full qualification will be attained when the testing and analysis plans developed to address the ASR issues are completed and the long term resolution is incorporated into the UFSAR and/or other applicable design documents.

Comment [wjr1]: Add a statement here that NRC review found the ODs acceptable. There is a need for the agency to take a stand on operability based on "best available" info. Then the rest will follow regarding the need to continue to review operability as new information is obtained.

Based on the technical guidance in Section 6.2 of the NRC Inspection Manual: Part 9900 – Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety (Reference 17), an SSC that is determined to be operable but degraded or nonconforming is considered to be in compliance with its TS LCO, and the operability determination is the basis for continued operation. The basis for continued operation should be frequently and regularly reviewed until corrective actions are successfully completed. Using information

from the ongoing detailed investigations of the ASR issue by the licensee, the PODs should be re-assessed based on the results of the licensee's testing and detailed engineering evaluation scheduled to be completed in March 2012.

(b) Although several documents in the form of contractor/consultant recommendations were made available, the licensee has not yet made available to the NRC its firm Action Plan to address the ASR issue at Seabrook. Also, licensee plans have been changing. In order to make an objective assessment of the licensee's ongoing actions to address the ASR issue, the licensee should finalize and make available, in the immediate future, for available for NRC review a firm and comprehensive Action Plan (not contractor/consultant recommendations) for the effects of ASR on Seismic Category 1 concrete structures at Seabrook in support of the interim and long-term design basis evaluations of affected structure and aging management of the issue. This should be an Appendix B quality document. This action plan should include the systematic strategy for the root cause, diagnosis, prognosis, structural appraisal, aging management and potential mitigation of the ASR-degradation issue of concrete structures at the station.

(c) The issues and questions raised in the license renewal application NRC RAI Follow-up B.2.1.31-1 (Reference 18, ADAMS Accession No. ML11178A338) dated June 29, 2011, are considered comprehensive. All the issues raised also apply for addressing the ASR issue during the remaining period of the current 40-year operating license, under 10 CFR Part 50. In addition, further consideration should be given to the issues in Items (d) thru (i) below in the response to TIA Question 1 and the responses to TIA Questions 2 to 5.

(d) Since the ASR-degradation of important-to-safety concrete structures at Seabrook is a significant condition adverse to quality, the licensee should address the root cause and corrective action pursuant to Criterion XVI "Corrective Action" of 10 CFR 50 Appendix B.

(e) Groundwater samples that have been collected and tested as part of the license renewal project determined that the ground water environment at Seabrook Station is aggressive due to elevated chloride levels greater than 500 mg/L (EC 145305). Areas impacted by ground water are currently designated as harsh environment. Further, the ASR-affected B Electrical Tunnel Walls showed ground water in-leakage, and efflorescence and leaching of salts on the inside. Since ASR interacts with other deterioration processes (Reference 30), other applicable degradation mechanisms for concrete and reinforcing steel and potential for further deterioration of ASR in combination with other degradation mechanisms should be addressed.

(f) The NRC staff understands that the licensee has been taking and testing core samples from the interior of the ASR-affected structures. The licensee should address the degradation effects through the wall-thickness and especially on the exterior of the affected structures in contact with the soil and ground water, which may likely be more severe if the source of moisture is water infiltration from the outside.

(g) The licensee should address the effect of ASR on the bond between concrete and reinforcement in the affected structures.

(h) Since the effects of ASR on the design basis appraisal and aging management actions are dependent on the severity of ASR (measured as expansion-to-date and other considerations), the licensee should determine severity in a reliable manner by more than one method. The licensee should consider conducting stiffness damage tests of cores in the laboratory in addition to in-situ surface crack mapping to determine the severity.

(i) If the ASR-degradation of an affected important-to-safety structure at Seabrook is determined to be severe to very severe, the licensee should consider consulting experts for appropriate nonlinear finite element modeling of ASR-effects for detailed structural appraisal of the affected structure.

Comment [wjr2]: I would add requirement (j) – "In the Action Plan, provide a commitment and schedule to obtain core samples from all Category I concrete structures to confirm the presence or absence of ASR degradation."

Question 2:

Because the original design basis assumes no ASR is present during the design life of the structure, what, if any, are the specific original design assumptions affected by the presence of ASR that are not clearly evident in the UFSAR design basis?

[Discussion by Region 1: For example several calculation methods such as the relationship between compressive strength and modulus of elasticity to shear capacity and shear force are used in the seismic analysis. These assumed relationships may not be valid with ASR present in the structure.]

Response:

(a) The design basis of the Seismic Category 1 Structures affected by ASR, including the "B" Electrical Tunnel is described in Seabrook Station UFSAR (Reference 14), Section 3.8.4 "Other Seismic Category 1 Structures." UFSAR Section 3.8.4.4.a states that reinforced concrete design of Category 1 structures was in accordance with the strength design procedures of the **ACI 318-71 code** (Reference 22), except as indicated in Subsection 3.8.4.5. UFSAR Section 3.8.4 contains physical descriptions, codes, loads and load combinations, design and analysis procedures, structural acceptance criteria (e.g., allowable stresses), quality control, and testing requirements of Seismic Category 1 structures exclusive of the containment structure and its internals. The basic load combinations considered in the design of each seismic Category 1 structures are given in UFSAR Table 3.8-16. Detailed design criteria are documented in NextEra system description document No. SD-66 "Structural Design Criteria."

UFSAR Section 3.8.4.5.d states that no special allowance has been made for variation of material properties over the life of the structure, beyond that which is taken into account in establishing allowable stresses, strains, capacity reduction factors, concrete protection of reinforcing, and crack control as outlined in the referenced ACI and AISC codes. Additional corrosion protection is provided to concrete structures by means of

waterproofing for parts of the structure below grade and by painting, coating or installing of liners for structural concrete tanks (such as the spent fuel pool).

(b) The presence of ASR generally show a reduction in the mechanical properties of concrete (relative to their 28-day values and measured on unrestrained core or cylinder specimens) such as compressive strength (f'_c), tensile strength (f_t), shear strength (v_c), bond strength, elastic modulus (E_c), and potentially an increase in the Poisson's ratio (ν). However, the change in these properties due to the presence of ASR occurs at different rates than the compressive strength in the same concrete. There are relationships between the compressive strength and other mechanical properties (namely, tensile, shear, bond, elastic modulus) of concrete used in design which are expressed empirically (based on tests of non-degraded concrete) in the ACI 318 code as a function of the square root of the compressive strength of concrete, f'_c, that may not remain valid for structures affected by ASR degradation, depending on the severity of the degradation. It should be noted that, in general, all relationships in the ACI 318 code that are expressed as a function of $\sqrt{f'_c}$ depend chiefly on the concrete tensile strength rather than compressive strength (Reference 34).

It has been established in literature that ASR reduces the tensile strength of concrete more rapidly than it reduces compressive strength (Reference 30). Thus far, the licensee has established by testing of selected cores of ASR-affected concrete from the B Electrical Tunnel that the measured modulus of elasticity was outside the range calculated and expected using the ACI relationship.

The relationships that may not remain valid for ASR-affected concrete, depending on the severity, are located in the following sections of ACI 318-71:

(i) Relationships in Section 8.3 of ACI 318-71 to calculate modulus of elasticity of concrete, E_c.
(ii) Relationships in Chapter 11 of ACI 318-71 for design for shear and torsion that are expressed as a function of $\sqrt{f'_c}$. As an example, the equations to calculate nominal permissible shear stress carried by concrete, v_c, in Section 11.4 of ACI 318-71. Also, see Section C(e) of AR 581434, Revision 1.
(iii) Relationships used to estimate tensile strength of concrete, f_t, for design of anchorages and embedments. Typically, it is estimated as $f'_t = 4\sqrt{f'_c}$. See Section C(d) of AR 581434, Revision 1.
(iv) Relationships in Chapter 12 of ACI 318-71 that are used for the calculation of reinforcement development length, l_d, which is design for bond between reinforcement and concrete.

(c) The NRR staff notes that the licensee's Prompt Operability Determination (AR 581434, Revision 001) for the B Electrical Tunnel (AR 581434, Revision 1) is based on the fundamental assumption that the empirical relationships (based on non-degraded concrete) in the ACI 318 code discussed in (b) above are not affected and remain valid for the ASR-degraded concrete. Therefore, the licensee must address the validity of this assumption for the ASR-degraded structure and its impact on the design basis evaluation in the final resolution of the operability determination.

(d) The presence of ASR in the affected concrete structure results in the reduction or change in the mechanical properties (namely, elastic modulus, poisson ratio, compressive strength and tensile strength) typically used in analysis/design of concrete structures. Therefore, the structural analysis (global and local) and design evaluation of the ASR-affected structure under design basis loads and load combinations should be based on actual measured material properties and how these properties were affected by ASR expansion rather than assumed or standard properties or relationships. Consistent with the guidance in Section 5.3 "Conditions requiring further evaluation" of ACI 349.3R, this requirement is also reflected in Section 5.3 in Attachment 1 of implementing procedure EDS 36180, Revision 1, for the structural monitoring program at Seabrook. The licensee should also establish whether or not the values of the mechanical properties of the ASR-affected concrete are currently within the normal range of values generally observed for concrete.

Question 3:

What is the appropriate ACI standard to be used for degraded concrete core sampling assessing in-situ ASR degradation for the control building (locations, numbers, frequency of sampling in the future, etc)?

[Discussion by Region 1: While this is an issue raised based on staff questioning, we need to know the regulatory or other basis for the use of either of two applicable standards or other more appropriate standard. One standard is ACI 228 used by NextEra for correlation to penetration resistance probe data and the other is ACI 214 (version 1965 is referenced in the UFSAR section 3.8.2.4). It should be further noted that a later revision of ACI 214 (ACI-214.R-03) provides for additional sampling in order to achieve a 95% confidence level. The ACI 228 appears to be met by NextEra but it requires less sampling. These standards were developed for general design and construction of concrete structures for non-nuclear applications. Technical research may be needed in order to determine their relevance for nuclear application in which the structures are heavily reinforced with rebar.]

Response:

The appropriate sampling plan for core sampling of degraded concrete depends on the objectives and scope of the investigation, the type of testing, and the role of the specific testing with respect to the degradation being addressed. In general, the purpose of an investigation for alkali-silica reaction (ASR) degradation of important-to-safety concrete structures at Seabrook is to gain necessary information and data to determine the cause and fully characterize, evaluate and manage the effect of ASR (diagnosis, prognosis and appraisal) on the design basis of the affected structure, both in the short term and long term. The diversity of mix characteristics as well as the range of damage and environment must be reflected in the sampling so that the sample is representative of the variability consistent with the objectives of the investigation and testing. Appropriate statistical methods should be used, where possible, for reliable evaluation of variations and interpretation of test results. The following guidance is provided with regard to standards that can be used for sampling determinations.

(a) The basic standard that provides guidance on statistically-based (probabilistic) sampling plan of hardened concrete in existing construction is ASTM C823 "Standard Practice for Examination and Sampling of Hardened Concrete in Constructions." This standard references among others: (a) ASTM Practice E 105 for recommendations on characteristics and minimum standards for developing a probability sampling plan in relation to the objectives of study, and practical constraints; (b) ASTM Practice E 122 for recommendations on sample size for samples to be subjected to tests yielding a numerical value, based on the degree of confidence desired to be placed on the result; and (c) Test Method ASTM C 42 for sampling procedures for securing samples of hardened concrete, including obtaining, preparing, and testing cores drilled from concrete for compressive strength, splitting tensile strength and flexural strength determinations of in-place concrete.

Pursuant to 10 CFR 50.65 (Maintenance Rule), the licensee is implementing the Structures Monitoring Program at Seabrook in accordance with standard technical procedure, EDS 36180, Revision 1, "Structures Monitoring Program." The regulatory basis for ASTM C823 is that the licensee's procedure EDS 36180 for the Structures Monitoring Program at Seabrook Station references ACI 349.3R "Evaluation of Existing Nuclear Safety-Related Concrete Structures" for evaluation criteria for concrete. Section 3.5.3 – "*Invasive testing*" of ACI 349.3R-02 states in part that "… Further information on material sampling and petrographic analysis is contained in ASTM C 42, C 823, and C 856. Similarly to NDE, the number of samples or tests taken and reliability of the obtained results are also important." Also, Chapter 5 of ACI 349.3R states in part that "For evaluations in which the primary goal is to determine material properties or retrieve samples for testing, the provisions of ASTM C 42 and C 823 should be followed to define the number and location of sampling points."

ACI reports including ACI 349.3R "Evaluation of Existing Nuclear Safety-Related Concrete Structures," ACI 214.4R "Guide for Obtaining Cores and Interpreting Compressive Strength Results," ACI 228.1R "In-place Methods to Estimate Concrete Strength," ACI 437R "Strength Evaluation of Existing Concrete Buildings" all reference ASTM C823 as the underlying standard for guidance with regard to retrieving samples for testing and test sample size determination in an existing concrete structure to be subjected to invasive (such as coring) and nondestructive testing methods.

(b) ACI 228.1R-03 "In-place Methods to Estimate Concrete Strength" provides guidance, including sampling, on the use of methods to estimate the in-place strength of concrete in new and existing construction based on in-place non-destructive test methods such as rebound number; penetration resistance, pullout, break-off number, ultrasonic pulse velocity, maturity, etc. In this Report, the principal application of in-place tests is to estimate the compressive strength of the concrete. These nondestructive tests do not directly measure the compressive strength of the concrete in a structure. Instead, they measure some other property that can be correlated to compressive strength and the general approach is to correlate results of in-place tests performed at selected locations with strength obtained by testing of corresponding cores. ACI 228.1R presents procedures for developing the relationship to estimate compressive strength from in-place tests, factors to consider in sampling and planning in-place tests and statistical techniques to interpret test results.

As part of the initial (preliminary) condition assessment (Reference EC 145305) of the B Electrical Tunnel structure for ASR, the licensee performed penetration resistance tests (PRT) and concrete core testing for estimating the in-situ compressive strength for the purpose of establishing if the in-situ compressive strength complies with strength used in original design. The cores were also used for petrographic examination for the presence of ASR degradation. ACI 228.1R is an acceptable standard to use for guidance on core sampling to establish the correlation between the PRT penetration measurement (or measurement from other in-place testing methods) and compressive strength. It is also appropriate standard for implementing, including sampling, non-destructive in-place testing methods described therein. ACI 228.1R is also referenced in ACI 349.3R, which is among the implementing documents referenced in the licensee standard procedure EDS 36180, Revision 1, "Structures Monitoring Program" at Seabrook Station.

Comment [wjr3]: Be more cautious in endorsing this standard: (i) the correlations do not account for ASR degradation and potential nonuniform variations in material properties; and (ii) NextEra gave up on this method since the PRT – core data did NOT correlate.

(c) ACI 214.4R-03 "Guide for Obtaining Cores and Interpreting Compressive Strength Results" includes guidance and methods for determining an in-place equivalent specified concrete design compressive strength to assess the structural capacity of an existing structure based on testing of cores. The guide presents procedures for obtaining and testing the cores, including determining sample size, and interpreting the results with a statistical basis that is consistent with the ACI 318 criteria.

If testing of cores are performed to determine the actual in-place design strength of the concrete for use in design evaluation, the strength determination should be made based on statistical evaluation of strength test results consistent with concrete quality provisions in Section 4.2 and 4.3 of ACI 318-71, which is the code-of-record for Other Category 1 Structures at Seabrook Station, including the B Electrical Tunnel. Therefore, if the purpose of core testing is to determine an actual in-place design compressive strength, f'c, (different from that used in original design) for use in the design evaluation of the ASR-affected structure, then ACI 214.4R is the appropriate guidance to use. The regulatory basis is that the statistical basis of the ACI 214.4R guidance is consistent with the statistical basis of the concrete quality, evaluation and acceptance provisions in Sections 4.2.2 and 4.3.1 thru 4.3.3 (also see commentary for these sections) of ACI 318-71, which is the construction code-of-record for "Other Category 1 Structures" at Seabrook Station, including the B Electrical Tunnel. As stated in Section 8.4 of ACI 214.4R-03, the confidence level used to estimate the equivalent specified strength should be 95% for important-to-safety structures in nuclear power plants.

Sampling for core testing that may be used to determine other types of in-place strength (such as shear strength which is a function of tensile strength) of the degraded concrete for design evaluation should have a similar statistical basis, as much as possible. The licensee should document the technical basis for adequacy of sampling used for tests used to determine in-place material properties of ASR-degraded concrete for use in analysis and design for the design basis evaluation of the degraded structure.

It should be noted that the statistical basis for concrete quality evaluation in the ACI 318 Code used for establishing the required average strength to assure attainment of the specified design compressive strength level, f'c, used in structural design stage, is based on ACI 214R. ACI 214R "Evaluation of Strength Test Results of Concrete" provides

guidelines and procedures for the statistical evaluation of concrete strength tests applicable to the compressive-strength test results required by ACI 301, ACI 318, and other similar specifications and codes. However, the focus of ACI 214R is with regard to molded cylinder strength tests of concrete sampled from the truck discharge or batch during original construction pours to verify compliance to the construction specifications, and not on existing structures. However, the statistical concepts therein could applied to the analysis of other concrete test results and similar concepts are applied in ACI 214R for evaluating core strength results.

(d) Although the licensee has made available documents that are contractor/consultant recommendations, the licensee has not yet made available a firm test plan technical document (of Appendix B quality) that it is being implemented for comprehensively addressing the ASR issue in the short-term and the long-term. The licensee should make available such a Test Plan (not contractor/consultant recommendations) in the immediate future. Core sampling or other methods of testing would be required to estimate the severity, expansion-to-date, potential for future expansion, monitoring trends, reinforcement assessment, etc., for the design evaluation and aging management of the ASR issue. It is recognized that obtaining large numbers of random samples in strict compliance with sound statistical procedures may not be always practical physically. Coring may have to be limited to a controlled number of samples to minimize any detrimental effects on remaining structural performance. It is important to obtain enough concrete representative of difference (variability) in materials used in construction, such as changes in cement, aggregates, and alternate mix proportions. Differing environmental conditions including loading, weathering, exposure to moisture, and age influence the behavior of the concrete and should be considered during the investigation. The licensee should consult ACI 349.3R and specialized literature on ASR such as those in References 30 and 31, or other expert sources on the issue for guidance in sampling for specialized tests. Also, it should be emphasized that the licensee should make the most effective use of removed core samples to obtain the maximum data that would enable proper characterization of the concrete. For all testing, the licensee should provide the technical basis and justification of the adequacy of their sampling plan consistent with the objective of the testing in regard to addressing the impact of the ASR degradation on the design evaluation of the affected structure. This technical basis should be documented in the test plan and/or the engineering evaluation that uses the information/data from the testing.

Comment [wjr4]: Can we better define this? For the ET, we now have a wall with (12 + 20 =) 32 cores removed. When does it become a problem?

<u>Question 4:</u>

Did NextEra perform adequate laboratory tests for core sampling, including appropriate parameters obtained along with laboratory test conditions?

[Discussion by Region 1: Also, during the course of this review, please identify the need for any in situ testing of control building conditions including appropriate parameters to be obtained such as temperature and humidity along with test conditions for now and in the future. Also, provide guidance on where and how much rebar should be exposed in order to assess the effect on rebar from the ASR issue.

No tensile strength testing is being performed on the concrete core samples and this question was raised in the RAI in terms of how shear capacity is being determined. However, the Region I staff believe that the specific parameter of tensile strength of concrete may not be sufficiently accurate and therefore relevant in a constrained structure. As the pressure load from the ASR gel increases, that load may be transferred to the rebar. Available research in this area appears to be conflicting. The UFSAR for containment assume concrete in reinforced systems provide no tensile strength.

A core sample with ASR does not represent the forces contained in the structure because for this test, in particular, elastic rebound is not considered. For split tensile tests on core samples, the frictional influences in the test itself are not accommodated. The frictional losses are further exacerbated by the standard laboratory practice of placing plywood on opposing faces of the tensile specimen to stop it from rolling off the test stand, thus restraining axial expansion of the sample.]

Response:

(a) The licensee has not made available to the NRC its firm Test Plan that it is implementing to address the ASR issue at Seabrook. In order to make an objective assessment of the testing, the licensee should finalize and make available, in the immediate future, for NRC review a firm and comprehensive Test Plan (not contractor/consultant recommendations) for testing concrete for the effects of ASR at Seabrook in support of the interim and long-term design basis evaluations of affected structure and aging management of the issue. This should be an Appendix B quality document. This plan should provide the different types of testing being performed or to be performed, the purpose of each test and how the results would be used in the engineering evaluation of the structure and aging management of the degradation.

(b) As discussed in the response to Question 2, since the presence of ASR in the affected concrete structure results in the reduction or change in the mechanical properties (namely, elastic modulus, poisson ratio, compressive strength and tensile strength) typically used in analysis/design of concrete structures, the structural analysis (global and local) and design evaluation of the ASR-affected structure under design basis loads and load combinations should be based using actual measured mechanical material properties established by testing of concrete in the affected structure.

(c) The walls of the Electrical Tunnel are so designed that shear forces are carried entirely by the concrete with no shear reinforcement. Review of drawings 9763-F-111342, -111343 and -111345 and Calculations CD-20 (original design calculation) and C-S-1-10159, Rev. 0, for the Electrical Tunnel Walls show that there is a vertical and horizontal layer of reinforcement on each face (inside and outside). There are no shear reinforcement ties or anchored stirrups through the thickness tying the two layers (this is a Class 3 reinforcement detail per Chapter 8 of Reference 30, and provides the least concrete confinement of the three details). Further Calculation CD-20, Appendix A (original design calculation) and C-S-1-10159 (for operability determination) that evaluated the wall for tranverse shear used higher concrete strength of 5458 psi(based on 28-day cylinder tests) and 4790 psi (based on core testing), respectively, in lieu of the

design compressive strength of 3000 psi, to qualify the wall for shear. As discussed previously, the tensile strength, bond strength and the shear strength of concrete could also be reduced by ASR-degradation. Tensile strength affects shear capacity of concrete and also its ability to support the loads of the attached embedments and anchorages supporting safety-related components. Therefore, it is critical that the licensee establish the actual shear capacity of the affected concrete for the design evaluation. The licensee should perform appropriate testing to establish data for evaluating the shear strength and bond strength of the affected-concrete and for evaluating the capacity of anchorages and embedments for important-to-safety components in the affected concrete. The licensee should provide technical justification for the appropriateness of the testing and evaluation methods they choose to use.

(d) The coarse aggregates used in Seabrook concrete is crushed granitic stone aggregate (Reference 11). In its response to license renewal RAI Followup B.2.1.31-1 (Reference 20), the licensee indicated that alkali reactivity tests of coarse aggregates would be performed per ASTM C 1260 "Mortar Bar Expansion Test" – short duration testing (16 days), ASTM C 1293 "Concrete Prism" – long duration testing (1-2 years), and other tests. In this regard, the staff notes that the ASTM C 1260 short-duration screening test is known to provide both false positives and false negatives (Reference 32), and expert opinion seems to indicate that this test may not effectively identify ASR reactivity in granite aggregates. The licensee should consider and evaluate the potential limitations of C 1260 test, especially in detecting ASR reactivity in granite aggregates, in selecting the short duration test method. Adapting a short duration test (14 to 16 days) such as the ASTM C 1567 "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)" may be a potential alternate test option.

Comment [wjr5]: Delete "conducted"

(e) In the appraisal of a structure for ASR degradation, it is important to measure the expansion to date in order to estimate the severity of the current degradation. The staff understands that the licensee is conducting in-situ surface crack mapping to arrive at a Cracking Index. The licensee should also consider performing the Stiffness Damage Test (Reference 31), which is an important laboratory mechanical core test for structural assessment: (i) to assess internal damage due to ASR, and (ii) to assess the expansion level reached to date. It is of particular value in evaluating the condition of structural components where internal damage occurs through the thickness or depth, but visible cracking is suppressed by heavy reinforcement.

(f) The ASR expansion and rate are a function of humidity and temperature conditions to which the concrete is exposed. It is important to measure these conditions on the ASR affected concrete. The actual temperature and humidity conditions seen in the field may need to be simulated in expansion tests to assess current and future expansion potential. The licensee should plan for "in-situ" monitoring of actual structure conditions such as temperature and relative humidity/moisture conditions, in addition to crack mapping.

Question 5:

Is the current NextEra structural monitoring program sufficient to discover or predict additional ASR damage to structures prior to the damage negatively impacting the design basis of the structure?

[Discussion *by Region 1*: To date three building assessments have been completed: control building, the containment, and the containment enclosure building. These assessments were initiated as a consequence of discoveries made preparing for a renewed license application. These discoveries should be reflected in enhancements to the programs required as part of the Maintenance Rule. The Region requests NRR assistance in evaluating the current acceptability of NextEra's programs to maintain the integrity of the safety related structures.]

Response:

The response is based on review of the [current] version of the licensee's implementing document for its structures monitoring program that was made available to the NRC staff, which is the NextEra Energy Structural Engineering Standard Technical Procedure EDS 36180, Revision 01, "Structural Monitoring Program," with an effective date of 3/15/2011. This document states that the procedure provides guidance for the conduct of the structural condition monitoring program pursuant to 10 CFR 50.65, the Maintenance Rule, to provide reasonable assurance that those structures are capable of fulfilling their intended functions. This document references Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

Attachment 3 of the licensee's implementing document for the Structural Monitoring Program (EDS 36180, Revision 1) incorporates a program for condition assessment of concrete subject to groundwater intrusion for ASR, which states: "A program to monitor the presence of ASR and the rate of change of concrete mechanical properties will be conducted at intervals of no more than five years. Methodology shall be similar to that outlined in EC 250348. The areas chosen shall be based on previous testing and potential ASR areas identified during Structural Monitoring Program walkdowns. The ASR assessment program shall be documented in the Structural Monitoring Program with Form 2 (Structural Deficiency Report – Initial Discovery), Form 3 (Structural Deficiency Report – Engineering Staff Review) and Form 4 (Structural Deficiency Report – Followup Inspection)." Attachment 2 of the procedure identifies groundwater intrusion areas.

The current determination made in the Prompt Operability Determination (POD) for the Electrical B Tunnel (AR 581434, Revision 001) is: "Affected SSC should be considered Operable but degraded, and below Full Qualification. Continued Operability is based on the provisions of RIS 2005-20." For this determination, based on the guidance in regulatory Position C1.5 in RG 1.160 for monitoring structures under the Maintenance Rule, the ASR-affected structure being degraded that it may not meet its design basis would be required to monitored in accordance with Paragraph (a)(1) of 10 CFR 50.65 (against performance criteria or goals) as opposed to paragraph (a)(2) condition monitoring. The structure would continue to be monitored in accordance with Paragraph (a)(1) until the degradation and its cause have been corrected. Further, for structures monitored in accordance with Paragraph (a)(1), additional

Comment [wjr6]: Reword – see suggested rewrite.

Comment [wjr7]: For this determination, based on the guidance in regulatory Position C1.5 in RG 1.160 for monitoring structures under the Maintenance Rule, the ASR-affected structure, being degraded *such* that it may not meet its design basis, would be required to *be* monitored in accordance with Paragraph (a)(1) of 10 CFR 50.65 (against performance criteria or goals) as opposed to paragraph (a)(2) condition monitoring.

degradation-specific condition monitoring and increased frequency of assessments would be required until the licensee's corrective actions are complete and the licensee is assured that the structure can fulfill its intended functions and will not degrade to the point that it cannot fulfill its design basis.

EDS 36180, Revision 01, only refers to ACI 349.3R for evaluation criteria for concrete. The evaluation guidelines in ACI 349.3R focus on commonly occurring conditions and are not meant to be all-inclusive. While ACI 349.3R is a good reference for evaluation of common degradations of concrete, it does not provide specific or detailed guidance on evaluating for ASR. The document needs to incorporate specialist literature or specialized evaluations that provides guidance specifically for the long-term ASR issue.

It is recognized that the licensee has a detailed investigation and engineering evaluation in progress for addressing the ASR issue at Seabrook both in the near term and long term, including prediction of the potential for future degradation. On the basis of the above discussion, the licensee's current structural monitoring program should be enhanced in the following respects for the ASR degradation-specific condition monitoring in order to be sufficient to discover or predict additional ASR damage to structures prior to the damage negatively impacting the design basis of the structure.

(a) The scope, procedure, personnel qualifications, and results of the 2011 detailed ASR walk-downs and extent of condition review must be incorporated into the program as ASR-specific baseline information for use and comparison during future monitoring and testing.

(b) The program should be enhanced to incorporate the applicable results of the ongoing testing and the detailed engineering evaluation of the ASR issue at Seabrook, currently scheduled to be completed by the licensee in March 2012. The program should be updated, as appropriate, for aging management related to ASR in the affected structures based on the engineering evaluation results during the remaining duration of its operating license.

(c) The program should be further enhanced, as applicable, based on the results of the long-term testing and/or evaluation that would be in progress beyond March 2012.

(d) The program should be updated to include degradation-specific guidelines for inspection and monitoring required to detect ASR degradation for structures not affected so far. The program should also be updated to include ASR degradation-specific guidelines and criteria for inspection and monitoring of ASR-affected structures including increased frequency assessments for condition monitoring of areas identified to be affected by ASR.

(e) The staff recommends that the licensee update the references for evaluation criteria and examination guideline for concrete in Sections 4.1 and 5.0 of Attachment 1 (Structures Monitoring Program Inspection Guidance) to EDS 36180 from ACI 349.3R-96 and ACI 201.1R-02 to the latest versions, which currently are ACI 349.3R-02 and ACI 201.1R-08. In Section 4.1 "General Examination Guidelines for Concrete," the licensee should

specify specific examination guidelines for ASR, based on their operating experience with the issue.

4.0 REGULATORY REQUIREMENTS

The regulatory requirements pursuant to 10 CFR Part 50 and guidance applicable to addressing the ASR-degradation of concrete in Other Seismic Category 1 Structures at Seabrook, which includes the B Electrical Tunnel, can be found in the following regulations and regulatory documents.

(a) 10 CFR 50.65, Maintenance Rule, as it relates to monitoring the performance and condition of structures, systems, or components (SSCs) in a manner sufficient to provide reasonable assurance that these SSCs are capable of fulfilling their intended functions. When the performance or condition of an SSC do not meet established goals, appropriate corrective action shall be taken.

(b) 10 CFR Part 50, Appendix B, as it relates to the quality assurance criteria for nuclear power plants.

(c) Criterion XVI "Corrective Action" of 10 CFR 50 Appendix B as it relates to implementing a corrective action program to assure that significant conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and non-conformances are promptly identified, cause addressed, and corrected.

(d) 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1 as it relates to structures, systems, and components being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

(e) 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design of the safety-related structures being able to withstand the most severe natural phenomena such as wind, tornadoes, floods, and earthquakes and the appropriate combination of all loads.

(f) 10 CFR Part 50, Appendix A GDC 4, as it relates to safety-related structures being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

(g) NUREG-0800, Standard Review Plan, Section 3.8.4 - Other Seismic Category 1 Structures

(h) Regulatory Guide 1.160, Revision 2 (March 1997), Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

5.0 CONCLUSION

Based on its review of TIA 2011-013 request, available documents, literature, information obtained at the NRC inspection during the period 9/26/11 – 9/30/11, and within the limitations of information available, the EMCB staff has provided reasonable technical guidance in this TIA response with regard to the issues related to the ASR degradation of concrete at Seabrook raised by Region 1 in the five questions in the TIA request. Specific technical guidance to the issues is provided in the responses to the questions. In order to enable staff to make a fully objective assessment, the licensee should make available to the NRC in the immediate future its firm Action Plan and Test Plan (which should be Appendix B quality technical documents) that it is implementing to comprehensively address the ASR-degradation issue of important-to-safety concrete structures at Seabrook Station.

6.0 REFERENCES

Note: References 1 thru ~~12~~ 13 are licensee documents made available on licensee's Certrec website.

Comment [wjr8]: EDS 36180 was also a Seabrook doc provided for staff review (Certrec).

1. Calculation C-S-1-10159, Rev. 0, 'B' Electrical Tunnel Transverse Shear Evaluation Supplement to Calculation CD-20

2. Calculation C-S-1-10150, Rev. 0, Effects of Reduce Modulus of Elasticity – 'B' Electrical Tunnel Exterior Walls

3. Calculation CD-20-CALC, UE Control and Diesel Generator Building Design of Material and Walls below grade for Electrical Tunnel and the Control Building (Original Design Calculation)

4. Drawings for Control Building Concrete (Electrical tunnel) 9763-F-111342, 9763-F-111343 and 9763-F-111345

5. Action Request (AR) 581434, Revision 000, Prompt Operability Determination Reduced Concrete Properties Below Grade in 'B' Electrical Tunnel Exterior Walls.

6. Action Request (AR) 581434, Revision 001, Prompt Operability Determination Reduced Concrete Properties Below Grade in 'B' Electrical Tunnel Exterior Walls

7. EC 145305, Condition Assessment of Control Building Concrete

8. AR 574120 Preliminary Test Results of Control Building Concrete

9. AR 581434 Test Results from Control Building Concrete Modulus Testing *(Results of petrographic analysis of 4 of the 12 CB cores identified the presence of moderate to severe ASR in the concrete)*

10. EC250348, Revision 002, Condition Assessment of Building Concrete

11. AR 01625775, Revision 000, Petrographic Analysis of Concrete Cores from Seabrook Station

12. System Description No. SD-66, Revision 2, System Description for Structural Design Criteria for Public Service Company of New Hampshire, Seabrook Station, Unit Nos. 1 and 2, 3/02/84.

13. Structural Engineering Standard Technical Procedure 36180, Revision 01, "Structural Monitoring Program," NextEra Engineering Department Standard, 3-15-2011

14. Seabrook UFSAR, Revision 12, Section 3.8.4, Other Seismic Category 1 Structures

15. NUREG-0800, Standard Review Plan, Section 3.8.4 – Other Seismic Category 1 Structures

16. Regulatory Guide 1.160, Revision 2 (March 1997), Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

17. RIS 2005-20, Revision 1 dated April 16, 2008, Attachment 1 "NRC Inspection Manual, Part 9900: Technical Guidance, Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety."

18. Letter dated 6-29-2011 from Richard Plasse, USNRC, to Mr. Paul Freeman, NextEra Energy Seabrook, LLC – Request for Additional Information for the Review of Seabrook Station License Renewal Application (specifically Followup to RAI B2.1.31-1 on pages 2-3) (ML11178A3380)

19. NextEra Energy Letter SBK-L-11154 to USNRC dated 8-11-2011, Docket No. 50-443, Seabrook Station Response to Request for Additional Information – NextEra Energy Seabrook License Renewal Application Request for Additional Information – Set 15 (Specifically Response to Follow-up to RAI B.2.1.31-1 on pages 5-8)

20. NextEra Energy Letter SBK-L-11063 to USNRC dated 4-14-2011, Docket No. 50-443, Seabrook Station Response to Request for Additional Information – NextEra Energy Seabrook License Renewal Application Request for Additional Information – Set 13 (Specifically Responses to Follow-up to RAI B.2.1.31-1 and -2 on pages 4-7) (ML11108A1310)

21. NextEra Energy Letter SBK-L-10204 to USNRC dated 12-17-2010, Docket No. 50-443, Seabrook Station Response to Request for Additional Information – NextEra Energy Seabrook License Renewal Application Aging Management Programs (Specifically Responses to RAI B.2.1.31-1, -2 and -3 on pages 36-39) (ML1035405340)

22. ACI 318-71, Building Code Requirements for Reinforced Concrete (with Commentary)

23. ACI 349.3R-02, Evaluation of Existing Nuclear Safety-Related Concrete Structures

24. ASTM C 823/C 823M – 07, Standard Practice for Examination and Sampling of Hardened Concrete in Constructions.

25. ACI 228.1R-03, In-Place Methods to Estimate Concrete Strength

26. ACI 214R-02, Evaluation of Strength Test Results of Concrete

27. ACI 214.4R-03, Guide for Obtaining Cores and Interpreting Compressive Strength Results

28. ACI 228.2R-98 (Reapproved 2004), Nondestructive Test Methods for Evaluation of Concrete in Structures

29. ACI 437R-03, Strength Evaluation of Existing Buildings

30. Structural effects of alkali-silica reaction – Technical guidance on the appraisal of existing structures, The Institution of Structural Engineers, London, UK, July 1992 and Addendum, April 2010

31. Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures, US Department of Transportation, Federal Highway Administration, January 2010

32. PCA R&D SN2892b, Evaluation of Alkali-Silica Reaction (ASR) Mortar Bar Testing (ASTM C1260 and ASTM C1567), PCA Durability Subcommittee – Concrete Technology, Portland Cement Association, 2009.

33. Popovics, S., Strength and Related Properties of Concrete – A Quantitative Approach, John Wiley & Sons, Inc., 1998.

34. Nilson, A.H., and Winter, G., Design of Concrete Structures, Eleventh Edition, McGraw-Hill Inc.

35. R. Park and T. Paulay, Reinforced Concrete Structures, John Wiley & Sons, 1975.