UNITED STATES
NUCLEAR REGULATORY COMMISSION
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June 10, 2013

MEMORANDUM TO: James M. Trapp, Chief
Seabrook Alkali-Silica Reaction Issue Technical Team Chairman
Engineering Branch 1
Division of Reactor Safety
Region 1

THRU: Michael L. Marshall, Jr., Chief
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FROM: Alice Erickson, Structural Engineer
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SUBJECT: POSITION PAPER - "ASSESSMENT OF ACI 318-71 AS DESIGN BASIS FOR CATEGORY I CONCRETE STRUCTURES AFFECTED BY ALKALI-SILICA REACTION AT SEABROOK STATION"

The purpose of the attached paper is to document the staff's position regarding the applicability of American Concrete Institute (ACI) 318-71, "Building Code Requirements for Structural Concrete," and understanding of the provisions provided in Section 1.4 and guidance provided in Chapter 20 of ACI 318-71 as it relates to the Seabrook Station current licensing basis (CLB).

To support ongoing oversight efforts of the alkali-silica reaction issue at Seabrook Station, the staff has performed a review of the relevant regulatory requirements, guidance documents, industry codes and standards, and Seabrook Station Updated Final Safety Analysis Report (UFSAR), and has determined that a distinction should be made between the method of evaluation relied upon for design considerations, i.e., the strength design method of ACI 318-71, and methods of evaluation for existing structures. The Seabrook Station UFSAR clearly documents the strength design method of ACI 318-71 along with NUREG-0800, "Standard Review Plan as the design bases for the Category I Structures, with the exception of primary containment. However, the method of evaluation for existing structures is not part of the current licensing basis described in the UFSAR.

Docket No. 50-443

Enclosure:
Position Paper

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301-415-1933

Assessment of ACI 318-71 as Design Basis for Category I Concrete Structures Affected by Alkali-Silica Reaction at Seabrook Station

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BACKGROUND

Historically, Seabrook Station has experienced groundwater infiltration through below grade portions of concrete structures. In the early 1990's, an evaluation was conducted to assess the effect of groundwater infiltration on the serviceability of concrete walls and concluded that there would be no deleterious effect, based on the design and placement of the concrete and on the non-aggressive nature of the groundwater. However, in 2009, NextEra tested seasonal groundwater samples to support the development of the License Renewal Application (LRA) and the results showed that pH values were between 5.8 and 7.5, chloride values were between 19 ppm and 3900 ppm, and sulfate values were between 10 ppm and 100 ppm, indicating that the groundwater had become aggressive [pH < 5.5, chlorides > 500 ppm, or sulfates > 1500 ppm]. Subsequently, in conducting a comprehensive review of the possible effects on concrete structures, in early to mid-2010, the licensee performed in-situ penetration resistance testing (PRT) and compression testing of concrete cores from the affected areas in the "B" electrical tunnel of the control building. The results showed a reduction in compressive strength and modulus of elasticity of the affected concrete. In September 2010, the applicant confirmed the presence of Alkali-Silica Reaction (ASR) through petrographic examination of samples taken from the concrete cores of the "B" electrical tunnel.

The licensee has made two prompt operability determinations (PODs) to address the effects of this issue for potentially affected structures. The first addresses the reduction in concrete compressive strength and modulus of elasticity below grade in the "B" electrical tunnel exterior wall, and the second addresses the reduced concrete modulus of elasticity below grade in the containment enclosure building (CEB), residual heat removal (RHR) equipment vaults, emergency feedwater (EFW) pumphouse, diesel generator fuel oil tank rooms, and some additional other Category I Structures. These additional Category I structures, identified as having the potential presence of ASR as a result of an extent of condition survey, include the condensate storage tank enclosure, control building makeup air intake, service water cooling tower, "A" electrical tunnel, fuel storage building, east pipe chase, west pipe chase, pre-action valve room, primary auxiliary building, service water pump house, mechanical penetration area, and waste process building. Except for the primary containment structure, the Seabrook concrete structures that have been identified thus far as affected or potentially affected by ASR generally fall under the classification of "Other Category 1 Structures" described in UFSAR Section 3.8.4. As of June 2012, both PODs conclude that the ASR-affected structures are *operable but degraded*, and *below full qualification*. NUREG-1430, "Standard Technical Specifications," defines *operable/operability* as "...capable of performing its specified safety function." Regulatory Issue Summary (RIS) 2005-20, Revision 1, which includes NRC Inspection Manual Part 9900 as an attachment, defines *degraded condition* as "one in which the qualification of an structure, systems, and component (SSC) or its functional capability is reduced." It further defines *full qualification* of an SSC as one that "conforms to all aspects of its [current licensing basis (CLB), including all applicable codes and standards, design criteria, safety analyses assumptions and specifications, and licensing commitments." Based on the definitions provided in Inspection Manual Part 9900, the "below full qualification" aspect of Seabrook Station's operability determination suggests that Seabrook Station is not meeting some aspect of its CLB. The licensee will have to resolve the current PODs with respect to the CLB, by a final corrective action in accordance with its procedures for operability determinations and functionality assessments, as part of its action plan to comprehensively address and manage the ASR degradation issue at the site.

This paper is not intended to cover all requirements that must be met for compliance with the CLB, but to focus on understanding the applicability of ACI 318-71, "Building Code Requirements for Structural Concrete," to which the affected structures were designed.

ACI 318-71 DOCUMENTED AS DESIGN BASIS

Seabrook Station UFSAR Sections 3.8.3 and 3.8.4 clearly document the [ultimate] strength design method of the ACI 318-71 (with Commentary), along with the Standard Review Plan (SRP) [NUREG-0800] as the design basis for the Category I Structures, with the exception of the primary containment. The basic load combinations considered in the design basis of each seismic Category 1 structure are given in UFSAR Table 3.8-16. Thus, the ACI 318-71 strength design method was used in conjunction with load combinations in the referenced UFSAR table as the current licensing basis to demonstrate compliance with GDC 1, 2, and 4, and to ensure that the intended functions would be accomplished for these concrete structures.

DISCUSSION ON ACI 318-71

ACI 318-71 is a Construction Code written in the context of new design and construction. The empirical relationships between concrete compressive strength and other material/mechanical properties (such as tensile strength, shear strength, bond, modulus of elasticity etc.), defined in this Code and relied upon for design, are based on performance and test data of normal concrete. These equations do not account for the effects of ASR and may not remain valid for ASR-affected concrete depending on the severity of the degradation; therefore, they should be treated with caution for ASR-degraded structures. The technical basis for establishing design adequacy of reinforced concrete structural systems with ASR degradation is not covered by the ACI 318-71 Code.

ACI 318-71 Chapter 1, Section 1.4, "Approval of Special Systems of Design or Construction," states that "[t]he sponsors of any system of design or construction within the scope of this Code, the adequacy of which has been shown by successful use or by analysis or test, but which does not conform to or is not covered by this Code, shall have the right to present the data on which their design is based to a board of examiners appointed by the Building Official. This board shall be composed of competent engineers and shall have the authority to investigate the data so submitted, to require test, and to formulate rules governing the design and construction of such systems to meet the intent of this Code. These rules when approved by the Building Official and promulgated shall be of the same force and effect as the provisions of this Code." This section is intended to allow new developments and methods of design, new materials, and new uses of materials that have not been covered by the Code in design and construction provided their adequacy is substantiated by data. The commentary for this section states that the provisions of Section 1.4 do not apply to strength evaluation of existing structures under Chapter 20. Thus, Section 1.4 is not intended to apply to strength evaluation of ASR-degraded structures.

For the purpose of clarification, Section 1.2.3 of the Code defines the Building Official as "the officer or other designated authority charged with the administration and enforcement of this Code, or his duly authorized representative." By law, the NRC has the regulatory jurisdiction over commercial nuclear power plants in the United States with the mission to protect public health and safety. As stated in the introduction section of the commentary for ACI 318-71, "the Code has no legal status unless it is adopted by government bodies having the police power to

regulate building design and construction." Therefore, by allowing the use of ACI 318-71 strength design provisions as the licensing basis for design and construction of Category 1 structures (except containment) at Seabrook, the NRC has provided legal status to the Code provisions that were used in the Seabrook safety analysis. Also, even though ACI 349 "Code Requirements for Nuclear Safety-Related Concrete Structures" was not published until after Seabrook Station's design was completed, Section 1.4, which is equivalent to Section 1.4 in ACI 318-71, replaced the term "building official" with "authority having jurisdiction." This is because the ACI 349 Code adapted and applied most of its provisions from ACI 318 specifically for nuclear safety-related structures (with the exception of containment) and, therefore, explicitly identifies the NRC as having this authority in the definitions section of the Code.

ACI 318-71 Chapter 20, "Strength Evaluation of Existing Structures," which is written in the context of strength deficiencies following construction, does provide limited guidance for structural assessments when doubt develops concerning the safety of a structure. Section 20.1 states that "if doubt develops concerning the safety of a structure or member, the Building Official may order a structural strength investigation by analysis or by means of load tests, or by a combination of these methods." The commentary for this section states that "typically such doubt may arise if the materials supplied are considered to be deficient in quality, if the construction is suspect, or if the structure does not satisfy the Code in some aspect." This again, implies that the considerations in Chapter 20 were intended to address construction defects/deficiencies in existing structures, and generally not intended for evaluation of degradation mechanisms and effects, especially those that could vary with time and alter the structural behavior of concrete. Chapter 20 of the ACI 318-71 Code was not used during original construction and is not part of the licensing basis of Seabrook structures.

The general requirements for analytical investigations provided for in Section 20.2 states that "a thorough field investigation shall be made of the dimensions and details of the members, properties of the materials, and other pertinent conditions of the structure as actually built." This means that the data relied upon in the analytical investigation must be based on measured properties of the in-situ conditions of the structure. Section 20.3 provides general requirements for load tests on the built structure and Section 20.4 provides requirements for load test on flexural members. The analytical strength evaluation based on linear elastic analysis (which is the Code basis) may have limited value for initial approximate assessment of the effects of ASR. The input to any analysis remains dependent upon the interpretation of the effects of ASR degradation which is often uncertain and subjective. The in-situ load test guidance provided in Chapter 20 has significant limitations and is not appropriate for understanding and comprehensively addressing structural behavior and performance of ASR-affected nuclear power plant structures for different critical limit states, at different levels and variation of degradation with time and space. Load tests on the as-built structure is not a practicable approach for the Seabrook Station ASR issue, especially for the affected below-grade structures and for performance assessment in shear, bond and anchorages for embeds and supports.

INTENT OF TESTING BEING CONDUCTED

In a public meeting held on April 23, 2012, to discuss the plans and schedule regarding concrete degradation due to ASR, NextEra presented several statements in their slides that provide some insight as to the intent of the testing being conducted at the University of Texas.

The following statements indicate that the testing will be used to support resolution of the PODs and to provide some basis for demonstrating that the effects of aging will be adequately managed for license renewal:

- Ongoing full scale testing is expected to validate assumptions and identify additional margin.

- Testing is anticipated to show that the performance of ASR-affected concrete structures is not compromised.

- Design parameters for ASR-affected concrete [derived from ASR-affected and control beams] will be compared to ACI Construction Code requirements and reconciled with Seabrook design basis calculations.

- Aging Management Program (AMP) criteria and frequency will be revised as the full-scale concrete beam test program develops.

- Ongoing testing programs are expected to identify additional structural margin.

Based on this information, the staff understands that the testing being conducted at the University of Texas will be used in the final corrective action for resolution of the PODs. However, the details as to how the testing will support the resolution of the PODs remain unclear to the staff. The staff also understands that the testing will no longer serve as a basis for the development of NextEra's aging management program; however, the results of the testing may inform certain elements of the program that NextEra is currently proposing.

ASSESSMENT

As was stated earlier, Seabrook Station's UFSAR clearly indicates that the Seismic Category I concrete structures, exclusive of the containment structure, were designed to meet the strength design requirements of ACI 318-71 for load combinations in UFSAR Table 3.8-16. As such, this Code is the Construction Code-of-Record that forms the current licensing design basis for the Category I structures.

The intent of this paper is to communicate that the strength design provisions of ACI 318-71 must be satisfied in order for Seabrook Station to demonstrate that the ASR-affected concrete structures will perform their intended safety function within the CLB; however, unless proven otherwise, the empirical relationships in the design provisions of the Code should be treated with caution because the Code provisions did not consider ASR concrete degradation effects. Additionally, because ACI 318-71 does not provide a technical basis for establishing the design adequacy of ASR-affected reinforced concrete structural systems using its strength design provisions, the technical basis by which NextEra demonstrates the ability of the ASR-affected structures to perform their intended safety function in compliance with the regulations may require a change to the CLB in the final corrective action for resolution of the current PODs. In which case, it is the licensee's responsibility to make the determination of whether a license amendment is required by evaluating the proposed change in the final corrective action, for establishing the long-term design adequacy of ASR-affected structures, according to the regulatory requirements contained in 10 CFR 50.59 "Changes, tests and experiments."

It is emphasized that the approach used for addressing specific concrete degradation issues (such as ASR) must be appropriate to the circumstances and the issue(s) being addressed, and cannot be generally prescribed in a construction code. The code and commentary cannot replace sound engineering knowledge, experience and judgment. The basic premise in design and construction codes for ASR as well as in the CLB for Seabrook is prevention by controlling the materials used in the concrete mix design at the time of construction. Therefore, the approach being pursued by the licensee, to a significant extent based on large-scale testing at UT- Austin, is technically the appropriate approach to address structural performance of ASR-affected Seabrook structures for limit states where gaps exist in the ASR literature.

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