LBP-20-09

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:

Ronald M. Spritzer, Chairman
Nicholas G. Trikouros
Dr. Sekazi K. Mtingwa

In the Matter of	Docket No. 50-443-LA-2
NEXTERA ENERGY SEABROOK, LLC	ASLBP No. 17-953-02-LA-BD01
(Seabrook Station, Unit 1)	August 21, 2020

INITIAL DECISION
(Ruling on the Reformulated Contention)

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ACRS	Advisory Committee on Reactor Safeguards
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
ASTM	American Society of Testing and Materials
C-10	C-10 Research and Education Foundation, Inc.
CEB	Containment Enclosure Building
CI	Cracking Index
CCI	Combined Cracking Index
DRI	Damage Rating Index
EPRI	Electric Power Research Institute
FEA	Finite Element Analysis
FHWA	U.S. Department of Transportation Federal Highway Administration
FSB	Fuel Storage Building
FSAR	Final Safety Analysis Report
FSEL	Ferguson Structural Engineering Laboratory
GDC	General Design Criteria
ISE	Institution of Structural Engineers
LAR	License Amendment Request
LSTP	Large-Scale Test Program
mm/m	millimeters per meter
MPR	MPR Associates, Inc.
NRC	U.S. Nuclear Regulatory Commission
NRR	NRC Office of Nuclear Reactor Regulation
NSHCD	No Significant Hazards Consideration Determination
NUREG	NRC Technical Report Designation
OBE	Operating Basis Earthquake
PDF	Portable Document Format
POD	Prompt Operability Determination
RAI	Request for Additional Information
RES	NRC Office of Nuclear Regulatory Research
SE	Safety Evaluation
SEM	Structural Evaluation Methodology
SGH	Simpson, Gumpertz, & Heger Inc.
SMP	Structures Monitoring Program

SSCs	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
UFSAR	Updated Final Safety Analysis Report

I. Introduction

This proceeding arose from a license amendment request (LAR) filed by NextEra Energy Seabrook, LLC (NextEra),[1] regarding the operating license for Seabrook Unit 1, in Seabrook, New Hampshire. The LAR revised the Unit 1 Updated Final Safety Analysis Report (UFSAR) to include methods for analyzing the impact of concrete degradation caused by the alkali-silica reaction (ASR) affecting seismic Category I reinforced concrete structures at Seabrook.[2]

On April 10, 2017, C-10 Research & Education Foundation, Inc. (C-10) timely filed a petition seeking a hearing on the LAR.[3] In LBP-17-7, this Board held that C-10 established its standing to intervene in this proceeding, and admitted Contentions A, B, C, D, and H, as modified by the Board. Under 10 C.F.R. §§ 2.319(j) and 2.329(c)(1) and pursuant to

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[1] Ex. INT010, Seabrook, License Amendment Request 16-03 - Revise Current Licensing Basis to Adopt a Methodology for the Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction (August 1, 2016) at PDF 1–3 [hereinafter Ex. INT010, Original LAR]. Ex. INT010, Original LAR is a 74-page unnumbered portable document format (PDF) file. For reference clarity, this Board will refer to all Original LAR pages using their PDF page numbers.

We note also that the exhibit number references we use in this proceeding begin with a three-letter party identifier, i.e., NER (for LAR applicant NextEra), NRC (for the NRC Staff), and INT (for intervenor C-10 Research & Education Foundation, Inc (C-10)), followed by the exhibit number, and then followed in some instances by the designator "-R" to indicate that the exhibit was revised after its original submission as a pre-filed exhibit.

[2] See id. at PDF 2. Seismic Category I structures, systems, and components (SSCs) include those necessary to control the release of radioactive material or otherwise mitigate the consequences of an accident. We shall occasionally refer to these seismic Category I structures simply as "Seabrook structures." See Ex. NRC088, Regulatory Guide (RG) 1.29, Seismic Design Classification for Nuclear Power Plants (July 2016) at 5 [hereinafter Ex. NRC088, RG 1.29].

[3] C-10 is a membership organization with more than 700 members. Its name has been shortened from the original, "Citizens within the 10-Mile radius (of Seabrook Station)" to C-10. The organization is a non-profit 501(c)(3) membership organization with the mission to protect public health and the environment surrounding Seabrook Station. C-10 Research and Education Foundation, Inc. Petition for [L]eave to [I]ntervene: Nuclear Regulatory Commission Docket No. 50-443 (Apr. 10, 2017) at 1 [hereinafter C-10 Petition]; [C-10] Response to U.S. NRC Staff's Ans. to [C-10]'s Petition for Leave to Intervene: Nuclear Regulatory Commission Docket No. 50-443 (May 12, 2017) at 2 [hereinafter C-10's Reply].

Commission precedent,[4] the Board combined Contention D with portions of Contentions A, B, C, and H that each alleged defects in the LAR's monitoring program, acceptance criteria, and inspection intervals.[5] The reformulated contention states:

> The large-scale test program, undertaken for NextEra at the [Ferguson Structural Engineering Laboratory], has yielded data that are not "representative" of the progression of ASR at Seabrook. As a result, the proposed monitoring, acceptance criteria, and inspection intervals are not adequate.[6]

On March 11, 2019, the NRC Staff (Staff) issued the license amendment to NextEra Energy Seabrook, LLC.[7] On September 24–27, 2019, the Board conducted an evidentiary hearing on the reformulated contention at the Newburyport City Hall Auditorium in Newburyport, Massachusetts.[8]

This Initial Decision resolves the reformulated contention, which is based on Contentions A, B, C, D, and H. In Part VIII, infra, we identify several aspects of the LAR that, if unaltered, would preclude a finding that the license amendment provides reasonable assurance of adequate protection of public health and safety (hereinafter reasonable assurance).[9] We further

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[4] Section 2.319(j) authorizes a Board to "[h]old conferences before or during a hearing for . . . [the] simplification of contentions," while 10 C.F.R. § 2.329(c)(1) authorizes a Board to hold a prehearing conference to consider matters including the "[s]implification, clarification, and specification of the issues." See Shaw AREVA MOX Serv's (Mixed Oxide Fuel Fabrication Facility), LBP-08-11, 67 NRC 460, 481–83 (2008) (describing licensing boards' authority to reformulate contentions); see also Crow Butte Res. Inc. (North Trend Expansion Project), CLI-09-12, 69 NRC 535, 552 n.79 (2009).

[5] LBP-17-7, 86 NRC 59, 127 (2017).

[6] Id. at 90.

[7] Ex. INT024, NRC Safety Evaluation Related to Amendment No. 159 to Facility Operating License No. NPF-86 (March 11, 2019) at 2 [hereinafter Ex. INT024, Final SE]. For clarity, this Board will reference the PDF page numbers in citations to this exhibit.

[8] See Tr. at 214–1203.

[9] See Atomic Energy Act § 182, 42 U.S.C. § 2232. Both the common standards for licenses and construction permits in 10 C.F.R. § 50.40(a), and those specifically for issuance of operating licenses in 10 C.F.R. § 50.57(a), provide that there must be "reasonable assurance" that the activities at issue will not endanger the health and safety of the public. Entergy Nuclear Operations, Inc. (Palisades Nuclear Plant), CLI-15-22, 82 NRC 310, 316 n.44 (2015).

conclude, however, infra Part IX.A, that the imposition of license conditions on these aspects of the LAR provides reasonable assurance. The license conditions include modifications to conditions imposed by the Staff[10] when it granted the LAR and modifications to the requirements of NextEra's ASR monitoring program. With the inclusion of the Board conditions in the license amendment, we conclude that it satisfies regulatory requirements. We therefore resolve the reformulated contention in favor of NextEra.

II. Background

A. Discovery and Evaluation of ASR at Seabrook

ASR is one type of alkali-aggregate reaction that can damage and degrade concrete structures.[11] The expansion of concrete and cracking from ASR can potentially impact the capacity[12] (i.e., structural properties) of a concrete structure by reducing the material properties (i.e., compressive strength, elastic modulus, and tensile strength)[13] of the concrete.[14] Concrete expansion caused by ASR can also lead to deformation of the structure itself and cause strains where the expansion is resisted by steel reinforcement or supports, other structures, or adjoining parts of the same structure that are outside the ASR-affected area.[15] Structural deformation caused by ASR can increase the load or demand on the structure, which, in turn, affects overall structural performance.[16]

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[10] See infra Part IX.A.

[11] Ex. INT010, Original LAR at PDF 8–9. The reaction is explained in more detail infra Part II.A. ASR and many other technical terms are defined in the Glossary, see infra app.

[12] Capacity is the ability to withstand applied loads, such as from an earthquake. Ex. NER001, MPR Testimony at 36.

[13] Id. at 39.

[14] See id.

[15] Ex. INT010, Original LAR at PDF 23.

[16] Id. at PDF 9–10.

NextEra first identified pattern cracking consistent with ASR at Seabrook in 2009.[17] Cracking was initially identified in the B Electrical Tunnel,[18] and, subsequently, in several other seismic Category I structures at the facility.[19] As a result, NextEra removed multiple concrete cores from the walls in several plant structures to confirm the presence of ASR.[20] In August 2010, NextEra completed the petrographic evaluation[21] of the concrete core samples, which confirmed ASR as the degradation mechanism.[22]

The degraded conditions of Seabrook seismic Category I structures were evaluated in the plant's Corrective Action Program via a prompt operability determination (POD) in August 2010[23] that later went through several revisions.[24] In 2012, NextEra completed an interim evaluation that assessed the structural adequacy of the reinforced concrete structures affected by ASR and the system/component anchorages in the ASR-affected concrete.[25] The evaluation found that the affected reinforced concrete structures would remain suitable for continued

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[17] Id. at PDF 9.

[18] Id.

[19] Id.

[20] Id.

[21] "Petrographic examination involves microscopic examination of prepared concrete surfaces by a qualified petrographer. The examination assesses the overall quality of concrete, and can determine causes for concrete degradation." Ex. NER001, MPR Testimony at 48.

[22] Ex. NER018, MPR-3727, Rev. 1, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments" (Jan. 2014) and NextEra Supplements I-V Thereto (FP100716, Rev. 4) at 12 [hereinafter Ex. NER018, MPR-3727].

[23] Ex. NRC019, Confirmatory Action Letter, Seabrook Station, Unit 1 – Information Related to Concrete Degradation Issues (May 16, 2012) at 2.

[24] The initial PODs (Revisions 0 and 1) addressed the B Electrical Tunnel where ASR was first discovered. Five other buildings were identified as part of the extent-of-condition review and the evaluation of core samples taken from these structures. The PODs were updated as new information became available and revised analytical techniques were incorporated. See Ex. NRC082, Letter from Paul O. Freeman, NextEra, to NRC, "Seabrook Station Actions for Resolution of Alkali Silica Reaction (ASR) Issues" (May 10, 2012) at 2–3.

[25] Ex. INT010, Original LAR at PDF 10.

service for an interim period.[26] However, the evaluation noted that additional testing was required to evaluate the full design compliance of the concrete structures.[27]

On August 1, 2016, NextEra submitted its LAR.[28] The LAR revised the Seabrook Unit 1 UFSAR to include methods for analyzing the impact of concrete degradation caused by ASR on seismic Category I reinforced concrete structures.[29] The changes also limited allowable ASR expansion and established criteria for monitoring future changes due to ASR expansion and related structural deformation.[30] The three key elements of the LAR included the Large-Scale Test Program (LSTP),[31] the Structures Monitoring Program (SMP), and the Structural Evaluation Methodology (SEM). We will review each of these in turn.

Because the applicable building codes do not include provisions for the analysis of structures affected by ASR,[32] NextEra devised its own methodology and concluded that, despite the effect of ASR on the material properties of Seabrook concrete, Seabrook structures "will have strength close to or in excess of that envisaged in the original design or as required by the code."[33] NextEra based its methodology on the LSTP and its review of the existing technical literature.[34] The LSTP involved testing concrete specimens constructed by MPR Associates,

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[26] Id.

[27] Id.

[28] Id. at PDF 2.

[29] Id. at PDF 8.

[30] Id. at PDF 16–17, 30–37; see also id. at PDF 16–17.

[31] The LAR uses the terms "large-scale test programs" and "large-scale test program" interchangeably. See e.g., id. at PDF 15. In addition, some of the exhibits referenced in this order refer to the test program as the large-scale test programs, the FSEL, or the MPR/FSEL, but all refer to the same LSTP performed by FSEL. We will use the phrase LSTP throughout, regardless of how it was originally stated.

[32] Id. at PDF 11.

[33] Id. at PDF 15.

[34] Id. at PDF 10.

Inc. (MPR)—a consultant to NextEra—that purportedly reflected the structural characteristics of ASR-affected structures at Seabrook.[35] NextEra concluded that the LSTP was a better means to evaluate ASR's impact on structural performance than testing cores taken directly from the Seabrook Plant.[36] The Ferguson Structural Engineering Laboratory (FSEL), part of the University of Texas at Austin, performed the tests on the constructed specimens.[37]

The specimens used in the LSTP had ASR levels more severe than those found at Seabrook, but "the number of available test specimens and nature of the testing prohibited testing out to ASR levels where there was a clear change in 'limit state' capacity."[38] Because of the lack of testing data for more advanced levels of ASR, "periodic monitoring of ASR at Seabrook is necessary to ensure that the conclusions of the [LSTP] remain valid and that the level of ASR does not exceed that considered under the test programs."[39] The LAR, therefore, identified methods for monitoring ASR expansion. The SMP as modified by the LAR includes: (1) "periodic measurement of ASR expansion[;]" and (2) "periodic inspections of ASR-affected structures to identify and trend building deformation."[40]

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[35] Id. at PDF 15.

[36] See Ex. NRC001-R, Staff Testimony at 24 [hereinafter Ex. NRC001-R, Staff Testimony].

[37] Ex. INT010, Original LAR at PDF 15.

[38] Id. at PDF 17. A limit state is a condition of a structure beyond which it no longer fulfills the relevant design criteria. Id. at PDF 15.

[39] Id. at PDF 17.

[40] Id. at PDF 30–31. The SMP performs two functions. First, the program gathers expansion measurements from crack width measurements and extensometer readings at Seabrook for monitoring against specified acceptance criteria based on the LSTP to determine whether ASR-related expansion at Seabrook exceeds levels observed in the LSTP. Second, it gathers crack width and deformation measurements for monitoring against criteria established in the structural evaluations performed under the Structural Evaluation Methodology. Ex. NER001, Testimony of NextEra Witnesses Michael Collins, John Simons, Christopher Bagley, Oguzhan Bayrak, and Edward Carley ("MPR Testimony") at 59, 111–12, 113 [hereinafter Ex. NER001, MPR Testimony]; Ex. NER007, Seabrook Structures Monitoring Program Manual, Rev. 7 [PROPRIETARY] at 4-1.2 [hereinafter Ex. NER007, Seabrook [SMP] Manual Rev. 7] (non-public). The specific monitoring methods are discussed in more detail infra Part VIII.A.

The SEM evaluates both structural capacity and demands, or loads,[41] placed on the structures.[42] On the capacity side, the SEM uses Seabrook's existing UFSAR provisions on concrete capacities with the original design concrete specifications, so long as the Expansion Monitoring Limits in the SMP are not exceeded.[43] On the demand side, NextEra's evaluation concluded that ASR expansion in reinforced concrete resulted in a compressive load that should be combined with other loads already included in design calculations.[44] The LAR, therefore, included an analytical approach to account for the effects of ASR on design basis loads.[45] The SEM provides a methodology for calculating the ASR loads on a structure, based on in-plane expansion measurements such as crack width, pin-to-pin mechanical, and structural deformation measurements.[46] NextEra proposed several modifications to the Seabrook UFSAR to account for loads from ASR expansion in design calculations.[47] Incorporating the loads into

[41] "'Loads' are [f]orces or other actions that result from the weight of all building materials, occupants and their possessions, environmental effects, differential movements, and restrained dimensional changes. Permanent loads are loads in which variations over time are rare or of small magnitude. All other loads are variable loads." Ex. NER004, Testimony of NextEra Witnesses Said Bolourchi, Glenn Bell, and Matthew Sherman ("SGH Testimony") at 22 [hereinafter Ex. NER004, SGH Testimony].

[42] See id. at 15–20, 42–43.

[43] Id. at 17, 19–20; Ex. NER001, MPR Testimony at 60.

[44] Ex. INT010, Original LAR at PDF 20 tbl.2.

[45] Id. at PDF 16–17, 18–19, 23–30. Seabrook's original licensing basis includes methods for performing structural evaluations on Seabrook's Containment Building and certain other structures at the plant to ensure that they fulfill their safety-related functions following a design basis earthquake. Ex. NER001, MPR Testimony at 19.

[46] Ex. NER004, SGH Testimony, at 15–20, 32, 42–43; see generally Ex. INT022, Simpson Gumpertz & Heger, Methodology for the Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction (June 2018) [hereinafter Ex. INT022, SEM]. Ex. INT022, SEM is a 175-page PDF with multiple pagination forms. For reference clarity, the Board will cite to PDF page numbers.

[47] See Ex. INT010, Original LAR at PDF 24–30; Ex. NRC007, UFSAR § 3.8.

the UFSAR and evaluating structures using the appropriate properties for ASR-affected structural members is a change in methodology that requires NRC review and approval.[48]

As part of its SEM, NextEra uses a computational approach called a Finite Element Analysis (FEA) to understand the complex structures at Seabrook.[49] The FEA is a computational model that includes various elements to "collectively . . . simulate the structural geometry, stiffness, and mass" of the desired structure.[50] Modelers can add loads (i.e., demands), such as gravity, wind, or ASR, to the FEA to measure structural responses.[51] NextEra's stated goal in using the FEA is to "determine the structural forces, stresses, and deformations in the structural elements when required loadings are applied."[52] The FEA provides a methodology for calculating the ASR loads on a structure based on field measurements and structural deformation measurements.[53] After computing the total demands from ASR and other factors in the FEA, those demands are compared to the structural capacities (in this case, the capacities calculated using code equations and original material properties) to determine whether the structural integrity is within acceptable limits.[54]

B. C-10's Petition and the Board's Ruling on Standing and Contention Admissibility

On February 7, 2017, the NRC published a Federal Register notice of opportunity to request a hearing on the LAR.[55] In that notice, the Staff proposed "to determine that the

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[48] See infra Parts III.A.2–A.3.

[49] Ex. NER004, SGH Testimony at 21–22, 39–40.

[50] Id. at 39.

[51] Id. at 39–40.

[52] Id. at 39.

[53] Id. at 19–22, 44.

[54] Id. at 21–22, 39–40.

[55] Applications and Amendments to Facility Operating Licenses and Combined Licenses Involving Proposed No Significant Hazards Considerations and Containing Sensitive Unclassified Non-Safeguards Information and Order Imposing Procedures for Access to Sensitive Unclassified Non-Safeguards Information, 82 Fed. Reg. 9,601, 9,604 (Feb. 7, 2017).

amendment request involves no significant hazards consideration" under 10 C.F.R. § 50.92(c).[56] On April 10, 2017, C-10 timely filed a petition seeking a hearing on the LAR submitted by NextEra concerning the operating license for Seabrook.[57] C-10's Petition included ten contentions (Contentions A-J),[58] which outlined its concerns surrounding ASR-induced concrete degradation and its potential impacts on the concrete structures reinforcing the facility.[59]

On May 5, the Staff and NextEra filed answers to the Petition.[60] NextEra argued that C-10 failed to submit an admissible contention.[61] Although the Staff maintained that none of the original contentions, standing alone, were admissible,[62] it proposed that a reformulated contention that combined C-10's Contentions A, B, C, D, G, and H would be admissible.[63] The Staff maintained that C-10's remaining contentions were inadmissible.[64] C-10 did not object to the admission of the reformulated contention.[65]

In LBP-17-7, this Board admitted five contentions (Contentions A, B, C, D, and H) from the Petition.[66] The Board found each of those contentions to be "at least partially independently

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[56] Id.

[57] C-10 Petition at 1.

[58] Id. at 2–3.

[59] Id.

[60] NRC Staff's Ans. to [C-10] Petition for Leave to Intervene (May 5, 2017) [hereinafter Staff Ans. to Petition]; NextEra's Ans. Opposing [C-10]'s Petition for Leave to Intervene and Hearing Request on [NextEra]'s License Amendment Request 16-03 (May 5, 2017) [hereinafter NextEra Ans. to Petition].

[61] NextEra Ans. to Petition at 16.

[62] Staff Ans. to Petition at 26.

[63] Id.

[64] Id.

[65] LBP-17-7, 86 NRC 59, 89 (2017), aff'd, CLI-18-4, 87 NRC 89 (2018).

[66] See LBP-17-7, 86 NRC at 92–131.

admissible."[67] The details of each contention are set forth in detail in LBP-17-7,[68] but because the parties dispute the scope of the issues admitted for hearing, we provide a summary of each admitted contention below.

Contention A stated that "[v]isual inspection, crack width indexing, and extensometer deployment are not sufficient tools for determining the presence and extent of ASR in safety-related structures at Seabrook Station."[69] The Board concluded that Contention A was "inadmissible to the extent it concerns visual inspections" because the LAR's monitoring program does not depend on visual inspections.[70] But the Board found Contention A admissible as to the use of a combined cracking index (CCI) to monitor in-plane expansion (parallel to the underlying rebars)[71] and the use of extensometers to measure through-thickness[72] expansion (perpendicular to the underlying rebars).[73]

C-10's proposed Contention B stated that "[e]xpansion occurring within a reinforced concrete structure due to [ASR] is not equivalent to a [prestressing] effect. Any mitigation of lost structural capacity, due to reinforcement, is temporary and unpredictable."[74] According to C-10, NextEra's claim that ASR-impacted concrete held under "restraint" by steel rebar "increases in

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[67] Id. at 126–27.

[68] Id. at 92–137.

[69] C-10 Petition at 2.

[70] LBP-17-7, 86 NRC at 95.

[71] Ex. INT010, Original LAR at PDF 16.

[72] Several terms have been used during this proceeding to discuss through-thickness expansion, such as radial and horizontal expansion. Both terms are synonymous with through-thickness expansion. For clarity, we will use the phrase "through-thickness," although exhibits and witnesses may have used a different phrase.

[73] LBP-17-7, 86 NRC at 95; Ex. INT010, Original LAR at PDF 16.

[74] C-10 Petition at 4 (emphasis omitted). "Prestressing of concrete refers to the approach of applying a compressive load to improve the tensile capacity of the concrete member. . . . Because concrete is much stronger in compression than tension, prestressing can improve in-service performance for certain applications." Ex. NER001, MPR Testimony at 38.

strength reflects a false understanding of the forces at work."[75] C-10 asserted that the concrete may "show a temporary increase in certain measures of strength, but irrevocably will advance toward failure."[76] According to C-10, "[t]he danger in misconstruing the effects of ASR, acting within the restraint imposed by reinforcing steel, is that serious degradation . . . may go unnoticed without employing thorough petrographic analysis."[77]

The Board concluded that C-10's argument was "sufficient to establish a significant link between the claimed deficiency and the agency's ultimate determination whether the applicant will adequately protect the health and safety of the public."[78] The Board agreed with the Staff, however, that it need not resolve the "theoretical question" whether ASR-induced expansion within a reinforced concrete structure causes an effect that is equivalent to prestressing.[79] The Board, therefore, restated Contention B to read:

> The LAR misconstrues expansion occurring within a reinforced concrete structure due to the Alkali-Silica Reaction because any mitigation of lost structural capacity, due to reinforcement, is temporary and unpredictable.[80]

Contention C repeated Contention B's demand for thorough petrographic analysis of Seabrook structures, along with the argument that the benefit from ASR expansion in reinforced concrete is only temporary because microcracking will eventually lead to an "autocatalytic collapse of the concrete's properties."[81] The Board admitted Contention C because it provided additional expert arguments in support of C-10's demand for thorough petrographic analysis.[82]

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[75] Id. at 5.

[76] Id. (emphasis omitted).

[77] Id. (emphasis omitted).

[78] LBP-17-7, 86 NRC at 106.

[79] Id. at 105.

[80] Id. at 107.

[81] C-10 Petition at 8.

[82] LBP-17-7, 86 NRC at 108–11.

Contention D, quoting the LAR, emphasized that "[a]pplication of the results of the [LSTP] requires that the test specimens be representative of reinforced concrete at Seabrook Station, and that expansion behavior of concrete at the plant be similar to that observed in the test specimens."[83] Contention D alleged that the LSTP yielded data not truly representative of the "non-linear advancement of ASR over the course of 35–40 years" in Seabrook concrete.[84] Contention D further emphasized that the LSTP could not be "substituted for the required comprehensive petrographic analysis of in-situ concrete at the Seabrook reactor."[85] The Board concluded that if Contention D is correct, reliance on the LSTP to support the proposed monitoring program, acceptance criteria, and inspection intervals undermines the LAR.[86] The Board, therefore, concluded that Contention D is admissible.[87]

Contention H stated that the monitoring intervals NextEra proposed for Tier 2[88] and Tier 3[89] areas were too long and too fixed to measure effectively the ongoing impacts of ASR on seismic Category I structures.[90] C-10 claimed that there was no real knowledge of the speed of concrete deterioration caused by advancing ASR, i.e., "there [was] no determination as to

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[83] C-10 Petition at 9 (quoting Ex. INT019, MPR-4273, Rev. 1, Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction (March 2018) (Enclosure 7 to Letter SBK-18072) at vi [hereinafter Ex. INT019, MPR-4273]; Ex. INT021, MPR-4273, MPR-4273, Rev. 1, Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction (March 2018) (Enclosure 7 to Letter SBK-18072) at vi [hereinafter Ex. INT021, MPR-4273] (non-public)).

[84] Id. at 10.

[85] Id. at 8.

[86] LBP-17-7, 86 NRC at 114.

[87] Id. at 121.

[88] Tier 2 structures are those areas with 0.5 millimeters per meter (mm/m) (0.05%) to 1.0 mm/m (0.1%) of in-plane expansion and are monitored every 30 months. See Ex. INT010, Original LAR at PDF 65.

[89] Tier 3 structures are areas with in-plane expansion measured at 1.0 mm/m (0.1%) or more. These areas are scheduled for inspection every 6 months. See id.

[90] C-10 Petition at 15.

whether ASR progresses at a steady rate or at an accelerating (or decelerating) rate" and therefore the SMP's monitoring intervals were not appropriately conservative.[91]

Under 10 C.F.R. §§ 2.319(j) and 2.329(c)(1) and pursuant to Commission precedent,[92] the Board combined Contention D with portions of Contentions A, B, C, and H that each alleged defects in the LAR's monitoring program, acceptance criteria, and inspection intervals.[93] We concluded that "[b]ecause of the interrelated nature of the five admissible contentions, consolidation will promote a more efficient proceeding."[94] We therefore reformulated the admissible portions of Contentions A, B, C, D, and H into a single admitted contention:

> The large-scale test program, undertaken for NextEra at the FSEL, has yielded data that are not "representative" of the progression of ASR at Seabrook. As a result, the proposed monitoring, acceptance criteria, and inspection intervals are not adequate.[95]

On October 31, 2017, NextEra appealed our admission of the reformulated contention, arguing the Board should have denied C-10's hearing request.[96] Both C-10 and the Staff opposed the appeal.[97] NextEra challenged the Board's determination regarding the consolidation of the five contentions which the Board found admissible and, finally, the admissibility of the single, reformulated contention.[98]

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[91] Id.

[92] See supra note 4.

[93] LBP-17-7, 86 NRC at 127.

[94] Id. at 90.

[95] Id.

[96] NextEra's Notice of Appeal of LBP-17-7 (Oct. 31, 2017); Brief in Support of NextEra's Appeal of LBP-17-7 (Oct. 31, 2017) [hereinafter NextEra's Appeal of LBP-17-7].

[97] [C-10] Response to NextEra's Appeal of LBP-17-7: Whereby the Atomic Safety and Licensing Board Granted Standing to [C-10] to Intervene in Docket No. 50-443-LA-2 and Admitted Five of Its Contentions (Nov. 22, 2017); NRC Staff Brief in Opposition to NextEra's Appeal of LBP-17-7 (Nov. 27, 2017).

[98] NextEra's Appeal of LBP-17-7 at 13–30.

The Commission affirmed the Board's decision in LBP-17-7 and found that NextEra had not demonstrated an error of law or abuse of discretion concerning the Board's decision to admit the reformulated contention.[99]

C. C-10's Emergency Motion

On February 13, 2019, C-10 filed an emergency petition that requested the Commission exercise its supervisory authority and reverse the Staff's no significant hazards consideration determination (NSHCD) and immediately suspend the license amendment and as well as suspend a separate, related decision to renew the Seabrook operating license.[100] Moreover, C-10 requested that the Commission "take other appropriate actions in this proceeding to ensure adequate consideration and resolution of the seismic risk implications of ongoing and increasing [ASR]-related degradation in the Seabrook containment and other concrete safety structures."[101] C-10 argued the Commission should review and reverse the Staff's NSHCD until after the adjudicatory hearing.[102] Further, C-10 asked the Commission to investigate best practices for ASR and provide guidance to the Staff for evaluating ASR-related safety risks.[103] Both NextEra and the Staff opposed the petition.[104]

On July 25, 2019, the Commission declined to grant C-10's requested relief.[105] The Commission first noted that the petition was procedurally improper since Commission

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[99] CLI-18-4, 87 NRC at 110.

[100] Emergency Petition by [C-10] for Exercise of Commission's Supervisory Authority to Reverse No Significant Hazards Determination and Immediately Suspend License Amendment and License Renewal Decisions (Feb. 13, 2019) [hereinafter Emergency Petition].

[101] Id. at 1–2.

[102] Id. at 3.

[103] Id. at 4, 16.

[104] NextEra's Ans. Opposing C-10's Emergency Petition (Feb. 25, 2019); NRC Staff's Ans. to C-10's Emergency Petition (Feb. 25, 2019).

[105] See CLI-19-7, 90 NRC 1, 2 (2019).

regulations explicitly "contemplate the issuance of an amendment to a reactor license during the pendency of a hearing on the amendment, as long as the NRC has first determined that the amendment involves no significant hazards consideration."[106] The Commission emphasized the distinction between a decision on the license amendment request, which requires reasonable assurance of adequate protection of the health and safety of the public and the common defense and security, and a NSHCD, which only addresses whether a hearing must be held before or after issuance of an amendment.[107] Further, the Commission reasoned that 10 C.F.R. §§ 50.58(b)(6) and 2.1213(f) bar C-10 from requesting a delay of the issuance of the license amendment by the Commission until the Commission reviews the Staff's NSHCD.[108]

Accordingly, the Commission declined the request to stay the effectiveness of the renewed license[109] and found no compelling reason to exercise its discretionary authority to immediately suspend the license amendment, finding C-10's "emergency" petition lacked legitimate urgency.[110] The Commission observed that C-10 failed to address the possibility that the license amendment could be altered to provide effective redress upon conclusion of the evidentiary hearing.[111] The Commission noted as well that the Board has the authority to revoke or place conditions on the license amendment if it determines the Staff should not have granted it.[112]

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[106] Id. at 8 (citing Atomic Energy Act of 1954 § 189a(2)(A), 42 U.S.C. § 2239(a)(2)(A); 10 C.F.R. §§ 50.91(a)(4), 50.92).

[107] Id.; see Final Procedures and Standards on No Significant Hazards Considerations; Final Rule, 51 Fed. Reg. 7744, 7749 (Mar. 6, 1986); see also 10 C.F.R. §§ 50.40, 50.92.

[108] CLI-19-7, 90 NRC at 8–9.

[109] Id. at 10.

[110] See id. at 10, 12.

[111] Id. at 10–11.

[112] Id. at 11 (citing Entergy Nuclear Vt. Yankee, LLC (Vermont Yankee Nuclear Power Station), CLI-06-8, 63 NRC 235, 238 (2006)).

D. Plant Tour

Before the evidentiary hearing, the Board determined that it would benefit from a plant tour of Seabrook. The Board's goals for the tour included (1) developing site familiarity and an understanding of the affected concrete structures at the plant; (2) viewing various ASR-affected areas; and (3) observing the Cracking Index (CI) and CCI methodologies as applied to typical ASR-monitoring.[113] The Board explained that the purpose of the tour was solely to enable the Board to better understand the evidence that the parties may submit during the evidentiary hearing for this proceeding.[114] Therefore, to the extent any party wanted the evidentiary record to reflect any matter observed or discussed during the tour, that party had to make an appropriate evidentiary submission to the Board that reflected such matters.[115]

On June 21, 2019, the Board, together with representatives from the Staff, NextEra, and C-10, viewed various core-sampling, monitoring, and extensometer locations at Seabrook. These included the Exterior Diesel Generator Building CCI panel and extensometer; the Exterior Fuel Storage Building (FSB) CCI panels and extensometers; the Exterior Containment Enclosure Building (CEB)/Equipment Hatch Missile Shield CCI panels; the Condensate Storage Tank Enclosure exterior CCI panels and extensometers; and the B Electrical Tunnel.[116] Subsequently, the Board and the other participants viewed additional CCI panels, extensometers, and coring locations placed in various areas and observed an extensometer model and a core sampling display.

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[113] See Licensing Board Memorandum (Concerning Plant Tour) (Apr. 29, 2019) at 2 (unpublished).

[114] See Licensing Board Memorandum (Confirming Plant Tour) (May 29, 2019) at 1 (unpublished).

[115] Id. at 1–2.

[116] See Joint Proposal Regarding Plant Tour (May 9, 2019) at 2.

E. Evidentiary Hearing

From September 24–27, 2019, the Board held an evidentiary hearing in Newburyport, Massachusetts, at the Newburyport City Hall Auditorium.[117] At the hearing, the Board received statements from counsel, heard testimony from witnesses for the Staff, NextEra, and C-10, and admitted party exhibits into the evidentiary record.[118] Subsequently, in an October 29, 2019 issuance, the Board adopted corrections to the hearing transcripts,[119] adopted redactions to the transcript of the closed hearing sessions conducted on Wednesday, September 25, 2019, and Friday, September 27, 2019, so as to allow for a publicly available version of those hearing sessions, and adopted the final exhibit list.[120]

On November 21, 2019, the Staff, NextEra, and C-10 submitted proposed findings of fact and conclusions of law.[121] Thereafter, the parties sought a time extension to submit responsive proposed findings.[122] On December 2, 2019, the Board granted the requested extension.[123] NextEra filed its Responsive Proposed Findings of Fact and Conclusions of Law

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[117] See Tr. at 214–1203.

[118] See Licensing Board Order (Adopting Transcript Corrections, Transcript Redactions, and Final Exhibit List) (Oct. 29, 2019) (unpublished).

[119] See id. at 2.

[120] Id.

[121] [NextEra]'s Proposed Findings of Fact and Conclusions of Law (Nov. 21, 2019) [hereinafter NextEra's Proposed Findings of Fact and Conclusions of Law]; NRC Staff Proposed Findings of Fact and Conclusions of Law for the Admitted Contention (Nov. 21, 2019) [hereinafter NRC Staff's Proposed Findings of Fact and Conclusions of Law]; [C-10]'s Proposed Findings of Fact and Conclusions of Law (Nov. 21, 2019). C-10 later submitted an Errata to its initial Proposed Findings of Fact and Conclusions of Law. C-10's Errata to Proposed Findings of Fact and Conclusions of Law (Nov. 27, 2019); see [Corrected] [C-10]'s Proposed Findings of Fact and Conclusions of Law (Nov. 27, 2019); see also [Redacted] [Corrected] [C-10]'s Proposed Findings of Fact and Conclusions of Law (Feb. 12, 2020).

[122] See Unopposed Motion for Extension of Time to Seek Leave to File Responsive Proposed Findings of Fact and Conclusions of Law (Nov. 29, 2019). At the evidentiary hearing, the Board instructed that the parties would need to seek leave to submit any responsive proposed findings. See Tr. at 1181 (Spritzer).

[123] Licensing Board Order (Granting Time Extension to File Motions for Leave to Submit Responsive Proposed Findings of Fact and Conclusions of Law) (Dec. 2, 2019) at 1

on December 13, 2019,[124] and then filed a corrected version on December 17, 2019.[125] Subsequently, C-10 moved for leave to submit a response to NextEra's Responsive Proposed Findings of Fact and Conclusions of Law.[126] The Board denied the motion because "such an additional round of filings would go well beyond the submissions authorized under 10 C.F.R. § 2.1209 and would unnecessarily add to the several hundred pages of proposed findings of fact and conclusions of law already before the Board."[127]

F. Motion to Compel Mineralogical Data

During the evidentiary hearing, a dispute arose as to whether NextEra should produce a document that compared the mineralogy of the Seabrook aggregate and the LSTP test specimen aggregate.[128] On September 30, 2019, C-10 moved to compel NextEra to produce "a document or documents containing data regarding the tested mineralogical components of aggregate in Seabrook concrete."[129] C-10 maintained that the production of the Seabrook aggregate data was necessary "to make a complete record for the resolution of the dispute

(unpublished). The Board tasked the parties with filing any motion seeking leave to file responsive proposed findings of fact and conclusions of law on or before Friday, December 13, 2019. Id. at 2. Additionally, the Board ordered that any motion be accompanied by the responsive proposed findings of fact and conclusions of law. Id.

[124] [NextEra]'s Motion for Leave to File Responsive Proposed Findings of Fact and Conclusions of Law (Dec. 13, 2019).

[125] [NextEra]'s Corrected Responsive Proposed Findings of Fact and Conclusions of Law (Dec. 17, 2019); see also [NextEra]'s Errata to Responsive Proposed Findings of Fact and Conclusions of Law (Dec. 17, 2019).

[126] [C-10]'s Response to NextEra's Motion for Leave to File Responsive Proposed Findings of Fact and Conclusions of Law (Dec. 18, 2019).

[127] Licensing Board Order (Granting NextEra's Motion for Leave to File Responsive Proposed Findings of Fact and Conclusions of Law) (Jan. 6, 2020) at 2 (unpublished).

[128] Tr. at 1080–81.

[129] [C-10]'s Motion to Compel Production of Mineralogy Data and Request for Opportunity to Submit Supplemental Written Testimony Regarding the Data (Sept. 30, 2019) at 1 [hereinafter Motion to Compel].

between the parties regarding the representativeness of the [LSTP test data]."[130] C-10 also requested "a reasonable opportunity for Dr. [Victor E.] Saouma[, C-10's expert] to give a written expert opinion on the comparability of the Seabrook aggregate with the LSTP test specimen aggregate."[131]

NextEra opposed the motion; the Staff did not file a response.[132] NextEra argued, among other things, that it already produced documents containing mineralogical data as part of its initial disclosures in January 2018.[133] In response, the Board issued a Request for Clarification from C-10, inquiring whether the disclosed documents contained the mineralogical data sought.[134] C-10 submitted a reply stating that NextEra's initial disclosures did not include the requested mineralogical data, and also requesting leave to file two additional exhibits.[135] Both NextEra and the Staff opposed the Motion to Submit Additional Exhibits.[136] On November 25, 2019, the Board granted C-10's Motion to Compel but denied its Motion to Submit Additional Exhibits.[137]

The Board established a schedule that required NextEra to produce "all documents within its possession, custody, or control not previously produced containing data regarding the

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[130] Id.

[131] Id. at 4.

[132] NextEra's Ans. Opposing C-10's Motions to Compel Production of Mineralogical Data and to Submit Additional Post-Hearing Testimony (Oct. 9, 2019).

[133] Id. at 3–4.

[134] Licensing Board Memorandum (Request for Clarification) (Oct. 16, 2019) at 2 (unpublished).

[135] [C-10]'s Response to ASLB Memorandum and Motion to Submit Additional Exhibits Regarding Petrographic Observations and Analyses of ASR at Seabrook (Oct. 28, 2019) at 2, 3–4.

[136] NextEra's Ans. Opposing C-10's Third Motion for Leave to File Supplemental Testimony (Nov. 6, 2019); NRC Staff's Ans. Opposing C-10's Motion to Admit Additional Exhibit and Testimony (Nov. 6, 2019).

[137] Licensing Board Order (Granting C-10's Motion to Compel Mineralogical Data and Request to Submit Supplemental Written Testimony Concerning the Data; Denying C-10's Motion to Submit Additional Exhibits) (Nov. 25, 2019) at 4 (unpublished).

tested mineralogical components of aggregate in Seabrook concrete."[138] Additionally, the Board provided an opportunity for Dr. Saouma to file "written testimony explaining how the newly produced data affects his evaluation of the comparability of the Seabrook aggregate and the LSTP test specimen aggregate."[139] Finally, the Board allowed both NextEra and the Staff to file written rebuttal testimony in response to Dr. Saouma's new written testimony.[140]

On December 5, 2019, NextEra produced one document in response to the Board order granting the Motion to Compel.[141] The document, titled "Santa Ana Aggregates,"[142] contained "an examination of aggregate samples from a New Mexico quarry (which was not used in Seabrook's concrete), along with a comparison of that aggregate to Seabrook's aggregate."[143] As permitted by the Board, C-10 filed Dr. Saouma's written explanation regarding that document.[144] Both NextEra and Staff submitted exhibits in response.[145]

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[138] Id. at 17.

[139] Id.

[140] Id.

[141] Letter from Paul M. Bessette, NextEra, to Diane Curran, C-10 (Dec. 5, 2019) (ADAMS Accession No. ML19339H135) [hereinafter NextEra Motion to Compel Letter].

[142] See id. attach. Santa Ana Aggregates Petrography Report (Jan. 8, 2013) (ADAMS Accession No. ML19339H136) [hereinafter Santa Ana Aggregates Report].

[143] NextEra Motion to Compel Letter at 1 (emphasis omitted).

[144] Ex. INT051-R, Supplemental Testimony of Victor E. Saouma, Ph. D Regarding Adequacy of Petrographic Documents to Support Mineralogical Comparison Between Seabrook Concrete and LSTP Test Specimens [hereinafter Ex. INT051-R, Dr. Saouma Supp. Testimony]. The Board admitted Ex. INT051-R on January 17, 2020. See Licensing Board Order (Admitting Exhibits, Closing the Record of the September 2019 Evidentiary Hearing, and Providing Additional Instruction for Supplemental Proposed Findings) (Jan. 17, 2020) at 1 (unpublished) [hereinafter Order Closing the Hearing Record].

[145] See Ex. NER077, Testimony of NextEra Witnesses John Simons, Christopher Bagley, Oguzhan Bayrak, Matthew Sherman, and Edward Carley in Response to Exhibit INT051-R [hereinafter Ex. NER077, NextEra Response to Ex. INT051-R]; see also Ex. NRC091, Staff Testimony in Response to Exhibit INT051-R [hereinafter Ex. NRC091, Staff Response to Ex. INT051-R]. The Board admitted both exhibits on January 17, 2020. See Order Closing the Hearing Record at 1.

Following the submission of the additional exhibits related to the mineralogical data, the Board closed the evidentiary record.[146] On January 31, 2020, the parties filed supplemental proposed findings of fact and conclusions of law, limited to the specific issues raised in Dr. Saouma's new testimony and the rebuttal testimony submitted by NextEra and the Staff.[147]

III. Legal Standards

A. Regulatory Framework

1. Seismic Category I Structures

Some Seabrook structures, systems, and components (SSCs), including their foundations and supports, are designated as seismic Category I structures[148] because they are designed to withstand the effects of an Operating Basis Earthquake (OBE)[149] and a Safe Shutdown Earthquake (SSE).[150] Seismic Category I SSCs are those necessary to ensure: "(1)

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[146] See Order Closing the Hearing Record at 2.

[147] [NextEra]'s Supplemental Proposed Findings of Fact and Conclusions of Law (Jan. 31, 2020); NRC Staff Supplemental Proposed Findings of Fact and Conclusions of Law (Jan. 31, 2020) [hereinafter NRC Staff's Supp. Proposed Findings of Fact and Conclusions of Law]; [C-10]'s Supplemental Proposed Findings of Fact and Conclusions of Law (Jan. 31, 2020). C-10 later submitted a redacted version of its Supplemental Proposed Findings of Fact and Conclusions of Law. See Redacted [C-10]'s Supplemental Proposed Findings of Fact and Conclusions of Law (Feb. 12, 2020) [hereinafter C-10's Redacted Supp. Proposed Findings of Fact and Conclusions of Law].

[148] "Equipment and components that are not classified as seismic Category I, and whose collapse or failure could result in the loss of safety function of a seismic Category I [SSC], are checked to confirm their structural integrity against collapse or failure due to SSE loadings." Ex. NRC007, Seabrook Station Updated Final Safety Analysis Report, Chapter 3, Design of Structures, Components, Equipment and Systems § 3.2.1 (Oct. 2017) [hereinafter Ex. NRC007, UFSAR]; see supra note 2.

[149] OBE is the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public will remain functional. SSE is the maximum earthquake potential for which certain structures, systems, and components, important to safety, are designed to sustain and remain functional. The OBE response spectra are obtained by multiplying the SSE response spectra by one-half. Ex. NRC007, UFSAR §§ 3.7(B).1.1, 3.7(N).

[150] Appendix S to 10 C.F.R. Part 50, "Earthquake Engineering Criteria for Nuclear Power Plants," requires that all nuclear power plants be designed so that certain SSCs remain functional if the SSE ground motion occurs. 10 C.F.R. pt. 50, app. S.

the integrity of the reactor coolant pressure boundary; (2) the capability to shut down the reactor and maintain it in a safe shutdown condition; [and] (3) the ability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures"[151] required by 10 C.F.R. §§ 50.34(a)(1) and 100.11. The pertinent quality assurance requirements of Appendix B to 10 C.F.R. Part 50 apply to all activities that affect the safety-related functions of seismic Category I SSCs at Seabrook.[152] Appendix S to 10 C.F.R. Part 50 requires that the design for all nuclear power plants allow for certain SSCs to remain functional if SSE ground motion occurs.[153] These structures are sufficiently isolated and protected from non-seismic Category I structures to safeguard their integrity from design basis events.[154]

2. Updated Final Safety Analysis Report, Section 3.8

The UFSAR contains design and licensing basis information for a nuclear power facility, including how the facility meets the regulatory requirements for the design and how the facility responds to various design basis accidents and events. Analytical methods of evaluation are a fundamental part of demonstrating how the design meets regulatory requirements and why the facility's response to accidents and incidents is acceptable. In cases where the analytical methodology is an essential part of the conclusion that the facility meets the required design bases, the UFSAR must describe the specific analytical methods, which are then subject to varying levels of NRC review and approval during licensing.[155]

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[151] 10 C.F.R. pt. 50, app. S. § III.

[152] See Ex. NRC088, RG 1.29 at 2.

[153] See 10 C.F.R. pt. 50, app. S.

[154] Ex. NRC007, UFSAR § 3.2.1.

[155] See 10 C.F.R. § 50.71(e).

Chapter 3 of the Seabrook UFSAR identifies, describes, and discusses the principal architectural and engineering design of those SSCs important to safety.[156] UFSAR section 3.8 includes the requirements for the design of seismic Category I structures at Seabrook.[157] Section 3.8.1 applies to the concrete containment building, and section 3.8.4 applies to other seismic Category I structures.[158] The LAR modified each of these subsections to incorporate the changes related to ASR material effects and loads. Additional LAR-proposed changes to other subsections of the UFSAR were necessary for limits on anchors in concrete walls and slabs affected by ASR, and to allow the use of ANSYS[159] computer software.[160]

10 C.F.R. § 50.59 sets forth the circumstances under which a licensee may make changes to its facility as described in its UFSAR,[161] make changes in the procedures described in the UFSAR, and conduct tests or experiments not otherwise specified in the UFSAR. The licensee may take such action without obtaining a license amendment if there is no change to

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[156] Ex. NRC007, UFSAR § 3.

[157] Id. § 3.8.

[158] Id. §§ 3.8.1, 3.8.4.

[159] ANSYS, Inc. is a software company that develops engineering simulations. NextEra used a model developed by ANSYS in simulating the effects of ASR on Seabrook concrete. See Ex. INT010, Original LAR at PDF 26, 30.

[160] The proposed changes to the specific subsections of the Seabrook UFSAR are described in Ex. INT011 and the UFSAR markup pages are provided in Attachment 1 to that exhibit. Ex. INT011, NextEra Energy's Evaluation of the Proposed Change Including Attachment 1 Markup of UFSAR Pages (Enclosure 1 to Letter SBK-L-16071) at PDF 40–70 [hereinafter Ex. INT011, Evaluation of the Proposed Change] (non-public). Ex. INT011, Evaluation of the Proposed Change, is a 70-page PDF with unnumbered pages. For reference clarity, this Board will refer to all pages with their PDF page numbers.

[161] Of particular importance to Seabrook, 10 C.F.R. § 50.59(c)(2)(viii) requires a licensee to obtain a license amendment pursuant to 10 C.F.R. § 50.90 before implementing a proposed change if the change would "result in a departure from a method of evaluation described in the FSAR (as updated) used in establishing the design bases or in the safety analyses." See Ex. INT010, Original LAR at PDF 35. This is just the type of change involved in the UFSAR revisions at issue in this proceeding.

the facility's technical specifications[162] and the licensing action does not fall into one of eight specific categories.[163] Under certain circumstances, however, a licensee must apply for a license amendment and obtain NRC's approval before it can implement any such proposed change.[164]

3. License Amendments

Under 10 C.F.R. § 50.90, whenever a licensee seeks to amend its license, including technical specifications in the license, it must file an application for amendment that fully describes the changes desired. "In determining whether an amendment to a license, construction permit, or early site permit will be issued to the applicant, the Commission will be guided by the considerations which govern the issuance of initial licenses, construction permits, or early site permits to the extent applicable and appropriate."[165]

Accordingly, pursuant to 10 C.F.R. § 50.57(a)(3) and (a)(6), a license amendment must provide:

> (3) . . . [R]easonable assurance (i) that the activities authorized by the operating license can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the regulations in this chapter; and . . . [that]
>
> (6) The issuance of the license will not be inimical to the common defense and security or to the health and safety of the public.[166]

Similarly, 10 C.F.R. § 50.40, entitled "Common standards," requires that "the Commission be persuaded, inter alia, that the applicant will comply with all applicable

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[162] See 10 C.F.R. § 50.59(c)(1).

[163] See id. § 50.59(c)(2).

[164] See id. §§ 50.59(c)(2), 50.90.

[165] See id. § 50.92(a).

[166] See id. § 50.57(a)(3), (6); see Gen. Pub. Utils. Nuclear Corp. (Three Mile Island Nuclear Station, Unit 2), LBP-89-7, 29 NRC 138, 190–91 (1989); see also Duke Power Co. (Catawba Nuclear Station, Units 1 & 2), LBP-82-116, 16 NRC 1937, 1946 (1982) (citing Va. Elec. & Power Co. (N. Anna Nuclear Power Station, Units 1 & 2), ALAB-491, 8 NRC 245 (1978)).

regulations, that the health and safety of the public will not be endangered, [and] that the issuance of the amendment will not be inimical to the health and safety of the public . . . ."[167]

Pursuant to the Atomic Energy Act, applicants seeking license amendments must demonstrate that the amended license "provide[s] adequate protection to the health and safety of the public."[168] Specifically, the Commission requires that "a license amendment request must provide sufficient documentation and analysis to show that the licensee has complied with the relevant requirements, thereby demonstrating that the amended license will continue to provide reasonable assurance of adequate protection of public health and safety."[169] Although the Commission has not defined "adequate protection," the phrase is synonymous with "no undue risk."[170]

In this proceeding, we are concerned with the effects of ASR on Seabrook's safety-related structures and structural components. NextEra must demonstrate with reasonable assurance that structures or components in the LAR will remain capable of fulfilling their intended functions under design basis loads and load combinations.[171] The Commission stated

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[167] 10 C.F.R. § 50.40; see N. States Power Co. (Prairie Island Nuclear Generation Plant, Units 1 & 2), ALAB-455, 7 NRC 41, 44 (1978); accord Tenn. Valley Auth. (Browns Ferry Nuclear Plant, Units 1, 2, & 3), ALAB-664, 15 NRC 1, 15–16 ("Prior to license issuance the NRC must first find reasonable assurance that the activities authorized by the amendment can be conducted without endangering the health and safety of the public, and in compliance with Commission regulations."), vacated and remanded on other grounds, CLI-82-26, 16 NRC 880 (1982); Fla. Power & Light Co. (Turkey Point Nuclear Generating Station, Units 3 & 4), LBP-81-16, 13 NRC 1115, 1120 (1981) (reviewing a proposed license amendment to determine whether it would "endanger the health and safety of the public").

[168] Atomic Energy Act § 182, 42 U.S.C. § 2232; see Union of Concerned Scientists v. NRC, 824 F.2d 108, 118 (D.C. Cir. 1987) (holding "the NRC need not demand that nuclear power plants present no risk of harm" to satisfy the adequate protection standard); Carstens v. NRC, 742 F.2d 1546, 1557 (D.C. Cir. 1984); CLI-19-7, 90 NRC at 8; CLI-18-4, 87 NRC at 110; Palisades, CLI-15-22, 82 NRC at 316; DTE Elec. Co. (Fermi Nuclear Power Plant, Unit 3), CLI-15-4, 81 NRC 221, 231 n.49 (2015).

[169] Palisades, CLI-15-22, 82 NRC at 316.

[170] See Union of Concerned Scientists, 824 F.2d at 119.

[171] 10 C.F.R. §§ 50.40(a), 50.57(a)(3)(i)–(ii).

that the "'[r]easonable assurance' [standard] is not quantified as equivalent to a 95% (or any other percent) confidence level, but is based on sound technical judgment of the particulars of a case and on compliance with our regulations."[172] In general, the Commission undertakes a case-by-case approach in making a reasonable assurance determination, considering all relevant facts and circumstances to reach a sound technical judgment that verifies an applicant's compliance with all applicable regulations.[173]

To date, however, no specific NRC guidance, regulatory standard, or nuclear industry guidance exists to address the effects of ASR on nuclear power plants.[174] Moreover, neither of the building codes applicable to Seabrook's safety-related structures contain methods to address the effects of ASR on the structural properties of seismic Category I structures.[175] Therefore, the Board must evaluate all the evidence within the scope of the reformulated contention, relying in large part on the testimony of qualified experts and the exhibits on which they rely to determine whether the reasonable assurance standard has been met.

In addition to satisfying the reasonable assurance standard, a licensee must comply with the applicable NRC General Design Criteria (GDC) for Nuclear Power Plants, specified in 10

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[172] AmerGen Energy Co., LLC (Oyster Creek Nuclear Generating Station), CLI-09-7, 69 NRC 235, 262–63 (2009); see AmerGen Energy Co., LLC (Oyster Creek Nuclear Generating Station), LBP-07-17, 66 NRC 327, 340 (2007), aff'd CLI-09-7, 69 NRC 235 (2009) (stating the reasonable assurance standard "is not susceptible to formalistic quantification" (i.e., 95% confidence) or mechanistic application); see also N. Anna Envtl. Coal. v. NRC, 533 F.2d 655, 667–68 (D.C. Cir. 1976) (rejecting the argument that reasonable assurance requires proof beyond a reasonable doubt and noting that the licensing board equated "reasonable assurance" with "a clear preponderance of the evidence").

[173] Oyster Creek, CLI-09-7, 69 NRC at 262 n.143; Entergy Nuclear Generation Co. (Pilgrim Nuclear Power Station), CLI-10-14, 71 NRC 449, 465–66 (2010).

[174] See Improved Identification Techniques Against Alkali-Silica Reaction (ASR) Concrete Degradation at Nuclear Power Plants, 84 Fed. Reg. 65023, 65023 (Nov. 26, 2019) (NRC denial of petition for rulemaking to set ASR standards).

[175] See Ex. INT010, Original LAR at PDF 11.

C.F.R. Part 50, Appendix A.[176] Here, the relevant GDCs are GDC 1 (Quality Standards and Records),[177] GDC 2 (Design Bases for Protection Against Natural Phenomena),[178] GDC 4 (Environmental and Missile Design Bases),[179] GDC 16 (Containment Design),[180] and GDC 50 (Containment Design Basis).[181] GDC 1, 2, and 4 apply to Seabrook seismic Category I structures, whereas GDC 16 and 50 apply only to containment structures.

GDC 1 requires that "structures, systems, and components [SSCs] important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed."[182] In addition, GDC 1 states "[w]here generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function."[183] GDC 1 also requires the implementation of a quality assurance program to assure "that these [SSCs] will satisfactorily perform their safety functions . . . ."[184] GDC 2 requires all SSCs to "be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions,"[185] whereas GDC 4 requires all SSCs to "be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation,

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[176] Each GDC is discussed in detail in the UFSAR. See Ex. NRC007, UFSAR § 3.1.

[177] Id. § 3.1.1.1.

[178] Id. § 3.1.1.2.

[179] Id. § 3.1.1.4.

[180] Id. § 3.1.2.7.

[181] Id. § 3.1.5.1.

[182] 10 C.F.R. pt. 50, app. A.

[183] Id. (emphasis added).

[184] Id.

[185] Id.

maintenance, testing, and postulated accidents, including loss-of-coolant accidents [and] . . . be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids . . . ."[186]

GDC 16 and 50, which apply to containment structures, such as those at Seabrook, require those structures to maintain a "leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded,"[187] and mandate that the internal components of the containment structure "can accommodate . . . the calculated pressure and temperature conditions resulting from any loss-of-coolant accident . . . ."[188]

Further, 10 C.F.R. Part 50, Appendix B provides quality assurance requirements for the design, manufacture, construction, and operation of SSCs that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.[189] Section III of Appendix B to 10 C.F.R. Part 50, "Design Control," requires that the applicable regulatory requirements and 10 C.F.R. § 50.2 defined design basis for those SSCs covered by Appendix B be correctly translated into specifications, drawings, procedures, and instructions.[190]

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[186] Id.

[187] Id.

[188] Id.

[189] See 10 C.F.R. pt. 50, app. B.

[190] Id. § III.

B. Legal Standards Governing this Proceeding

1. Burden of Proof

An Intervenor has the initial "burden of going forward,"[191] which requires an intervenor to establish a prima facie case[192] for claims asserted in the reformulated contention. The admission of a contention, by itself, does not satisfy the "burden of going forward."[193] An intervenor must "provid[e] probative evidence or expert testimony."[194]

The applicant bears the burden of proof for all matters on which an intervenor has satisfied its "burden of going forward," requiring the applicant to show by a preponderance of the evidence that it is entitled to the applied-for license.[195] Thus, NextEra must show by a preponderance of the evidence that "[t]here is reasonable assurance . . . that the activities authorized by the operating license can be conducted without endangering the health and safety of the public," and that all applicable regulations (which in this case would include GDC 1, 2, 4, 16, 50 and Appendix B to 10 C.F.R. Part 50) are satisfied.[196] For safety-related matters, there is

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[191] Oyster Creek, CLI-09-7, 69 NRC at 269 (quoting Consumers Power Co. (Midland Plant, Units 1 & 2), ALAB-123, 6 AEC 331, 345 (1973) ("The ultimate burden of proof on the question of whether the permit or license should be issued is . . . upon the applicant. But where . . . one of the other parties contends that, for a specific reason . . . the permit or license should be denied, that party has the burden of going forward with evidence to buttress that contention. Once he has introduced sufficient evidence to establish a prima facie case, the burden then shifts to the applicant who, as part of his overall burden of proof, must provide a sufficient rebuttal to satisfy the Board that it should reject the contention as a basis for denial of the permit or license.")).

[192] Pac. Gas & Elec. Co. (Diablo Canyon Nuclear Power Plant, Units 1 & 2), ALAB-653, 16 NRC 55, 72 (1981) ("Prima facie evidence must be legally sufficient to establish a fact or case unless disproved.").

[193] See Oyster Creek, CLI-09-7, 69 NRC at 268–70.

[194] Id. at 269.

[195] See 10 C.F.R. § 2.325; N. Anna Envtl. Coal., 533 F.2d at 667–68.

[196] 10 C.F.R. § 50.57(a)(3)(i)–(ii); see also id. § 50.40(a); Pac. Gas & Elec. Co. (Diablo Canyon Nuclear Power Plant, Units 1 & 2), ALAB-763, 19 NRC 571, 577–78 (1984); Oyster Creek, CLI-09-7, 69 NRC at 263.

no burden on the Staff, but a Board will consider the Staff's safety evaluation in reaching its determination.[197]

In sum, NextEra carries the burden of proof on the issue whether there is reasonable assurance that the operation of Seabrook, as modified by the LAR, will not endanger the health and safety of the public.[198]

In making a case-by-case determination of reasonable assurance, a licensing board must weigh the expert testimony and give an expert "due weight" proportionate to his/her expertise.[199] Any gaps in an expert's knowledge go to the weight of the testimony.[200] General expertise on a matter may be useful, even if there are knowledge gaps in specific areas.[201] A board may reject an expert's assertions, however, if they are based on no more than "a gut feeling" and the expert acknowledges that he "ha[d not] analyzed" relevant documentation.[202] If expert testimony is crucial to the outcome of a safety or environmental issue, the expert must "make available . . . sufficient information pertaining to the details of the analysis to permit the

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[197] Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), LBP-03-4, 57 NRC 69, 140–41 (2003) ("[U]nder the Commission's time-tested licensing and hearing processes, the Staff's evaluation of an applicant's proposal — reached as it conducts its independent evaluation of an applicant's proposal — is considered an integral part of the record that is developed regarding any contentions challenging what an applicant has put forward. Even though the Staff's position may not prevail at trial, it is presumed that the development and exploration of a contested issue will benefit from the Staff's analysis and presentation."). The Staff is required to submit certain documents into evidence. See 10 C.F.R. § 2.337(g).

[198] See Consumers Power Co. (Midland Plant, Units 1 & 2), ALAB-283, 2 NRC 11, 17 (1975).

[199] Carolina Power & Light Co. (Shearon Harris Nuclear Power Plant), LBP-01-9, 53 NRC 239, 250 (2001).

[200] Duke Energy Corp. (Catawba Nuclear Station, Units 1 & 2), CLI-04-21, 60 NRC 21, 29 (2004).

[201] Id. at 31 ("Unwarranted and inflexible barriers, such as too great an insistence on 'specific' knowledge in selected aspects of the subject, should not disqualify an expert witness who possesses a strong general background and specialized knowledge in the relevant field.").

[202] See Entergy Nuclear Operations, Inc. (Indian Point, Units 2 & 3), LBP-13-13, 78 NRC 246, 301 (2013).

correctness of the conclusion to be evaluated."[203] In other words, an expert must make available data used in analyses to support conclusions asserted in the expert's testimony to enable a licensing board "to make a reasoned judgment on the weight."[204]

IV. Seabrook License Amendment

A. NRC Staff Safety Evaluation

The Staff issued a draft Safety Evaluation (SE) for the LAR on September 28, 2018 and provided it to the Advisory Committee on Reactor Safeguards (ACRS) that same day.[205] Based on its review of the LAR and that Staff report, the ACRS concluded that "NextEra ha[d] undertaken substantial and thorough actions to identify, understand, and address [ASR]."[206] In addition, the ACRS found that "[t]he LSTP test samples were highly representative of the ASR-affected structures at Seabrook."[207] The ACRS did not provide any recommendations for modifying the proposed ASR monitoring programs in the LAR.[208]

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[203] Va. Elec. & Power Co. (N. Anna Nuclear Power Station, Units 1 & 2), ALAB-555, 10 NRC 23, 27 (1979) ("It is not unreasonable, however, to insist that where, as here, the outcome on a clearly defined and substantial safety or environmental issue may hinge upon the acceptance or rejection of an expert conclusion resting in turn upon a performed analysis, the witness make available (either in his prepared testimony or on the stand) sufficient information pertaining to the details of the analysis to permit the correctness of the conclusion to be evaluated.").

[204] See id. at 26.

[205] Ex. NRC047, Memorandum from James G. Danna, NRC, to Andrea D. Veil, NRC ACRS, "Seabrook Station, Unit No. 1 - Submission of Alkali-Silica Reaction License Amendment Request Draft Safety Evaluation to Support the Advisory Committee on Reactor Safeguards' Review of Seabrook License Renewal (CAC No. MF8260; EPID L-2016-LLA-0007)" (Sept. 28, 2018). Created by the AEA, the ACRS, among other duties, "reviews and reports on safety studies and applications for construction permits and facility operating licenses[.]" 10 C.F.R. § 1.13.

[206] Ex. NRC048, Letter from Michael Corradini, Chairman, ACRS, to Kristine L. Svinicki, Chairman, NRC, "Seabrook Station Unit 1 License Renewal Application: Review of Licensee Program Addressing Alkali-Silica Reaction" (Dec. 14, 2018) at 1.

[207] Id. at 3.

[208] Id. at 2–4.

Thereafter, on March 11, 2019, the Staff issued a final SE to accompany the requested Seabrook operating license amendment, denominated as License Amendment No. 159.[209] In the final SE, the Staff concluded that NextEra had "developed a representative test program and that it [was] reasonable to apply the conclusions of the [LSTP] to the structures at Seabrook within the bounds and limits of the test program, regardless of the results of material property testing on ASR-affected concrete cores."[210] The Staff, however, noting that "this [was] a first-of-a-kind approach," imposed a license condition with two components that "require[s] [NextEra] to implement actions to periodically confirm the continued applicability of the [LSTP] conclusions to Seabrook structures."[211]

B. NRC Staff Technical Conclusions

In the final SE accompanying the March 2019 license amendment, the Staff summarized its review of NextEra's methodology for analyzing structures affected by ASR at Seabrook.[212] The Staff reviewed NextEra's documentation of its proposed evaluation method and conducted audits.[213] Based on its review, the Staff concluded that NextEra's proposed method to evaluate seismic Category I structures affected by ASR "is acceptable and provides reasonable assurance that these structures [will] continue to meet the relevant requirements of 10 [C.F.R.] Part 50, Appendix A, GDC 1, 2, 4, 16 (containment only) and 50 (containment only) and 10 [C.F.R.] Part 50, Appendix B."[214]

The Staff based its conclusion on seven criteria. First, the Staff concluded that NextEra "met the requirements of GDC 1 by including ASR as a design-basis load and demonstrating

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[209] Ex. INT024, Final SE at PDF 2.

[210] Id. at PDF 40.

[211] Id.

[212] Id. at PDF 69–70.

[213] Id. at PDF 69.

[214] Id.

that Seabrook ASR-affected structures will continue to meet the requirements of [American Concrete Institute (ACI) 318-71] . . . for all design-basis loads and load combinations[.]"[215] Further, the Staff concurred that ACI 318-71[216] is the applicable code to be used based on the research conducted for the LSTP and due to the additional supplementation and modifications made to account for ASR in ACI 318-71.[217] Moreover, the Staff concluded that NextEra developed the LSTP in a manner adequately representative of Seabrook structures, and implemented the LSTP in accordance with quality assurance standards.[218]

Second, the Staff concluded that NextEra fulfilled the requirements "of GDC 2 by including ASR as a design-basis load and demonstrating that Seabrook ASR-affected structures will continue to meet the requirements of [ACI 318-71] . . . for all design basis loads and load combinations . . . under normal and accident conditions . . . ."[219] Third, the Staff concluded that GDC 4 is satisfied because ASR-affected structures will continue to comply with GDC 1 and 2, and "because the design-basis loads and load combinations include the dynamic effects associated with missiles, pipe whipping, and discharging fluids."[220]

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[215] Id. at PDF 69–70.

[216] There are two "codes of record" applicable to Seabrook. These two codes form part of Seabrook's licensing design basis regarding concrete structures. The first, ACI 318-71, applies to seismic Category I structures other than containment, while the second, ASME Code Section III, Division 2, applies to containment. See Ex. NRC001-R, Staff Testimony at 68; Ex. NRC049, American Concrete Institute (ACI) Standard 318-71, Building Code Requirements for Reinforced Concrete (1971) [hereinafter Ex. NRC049, ACI 318-71] (non-public); Ex. NRC050, Section III, Division 2, of the 1975 Edition of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) for Containment [hereinafter Ex. NRC050, ASME Code] (non-public).

[217] Ex. INT024, Final SE at PDF 69.

[218] Id.

[219] Id.

[220] Id.

Fourth, the Staff concluded that NextEra satisfied the requirements of GDC 16 and 50 by demonstrating the containment will continue to meet GDC 1 and 2 "for all design-basis loads and load combinations including ASR under normal and accident conditions."[221] Fifth, the Staff concluded that NextEra satisfied the applicable requirements in 10 C.F.R. Part 50, Appendix B because NextEra (1) implemented the LSTP under the quality assurance requirements, and (2) established a Structures Monitoring Program to monitor future ASR progression against the LSTP "expansion limits and the structure-specific design output threshold monitoring limits[.]"[222] Sixth, the Staff concluded that the proposed method of ASR evaluation "is acceptable subject to the limitation that measured ASR expansion on affected Seabrook structures is within the limits of the [LSTP] . . . ."[223] Finally, the Staff concluded that NextEra's "implementation of the future confirmatory actions required by the license condition . . . will provide assurance of the continued applicability of the [LSTP] conclusions to Seabrook structures."[224]

C. License Condition

In issuing the March 2019 Seabrook operating license amendment, the Staff included a license condition that requires NextEra to take specific actions to ensure the continued applicability of the LSTP to concrete structures affected by ASR at Seabrook.[225] This condition has two components. The first requires periodic assessments of ASR expansion using an approach identified in Appendix B of MPR-4273[226] to confirm that future ASR expansion is comparable to the data observed in the LSTP expansion program.[227] Additionally, in 2025 and

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[221] Id.

[222] Id. at PDF 69–70.

[223] Id. at PDF 70.

[224] Id.

[225] See id. at PDF 68–69.

[226] Ex. INT019, MPR-4273 app. B; Ex. INT021, MPR-4273, app. B (non-public).

[227] Ex. INT024, Final SE at PDF 68.

2035, NextEra must "[c]orroborate the concrete modulus-expansion correlation used to calculate pre-instrument through-thickness expansion, as discussed in Report MPR-4153."[228] NextEra stated that it would evaluate the need for changes if the periodic assessments suggest that the monitoring intervals or any other aspect of the SMP are insufficient.[229] Moreover, the license condition requires that NextEra must address "any adverse findings from the confirmatory actions in the license condition" in accordance with the Corrective Action Program, which is subject to further NRC oversight.[230]

Regarding any substantive differences in Seabrook concrete and the concrete used in the LSTP, the Staff found that the license condition provided additional assurance that any variances will not affect public health and safety.[231]

D. License Renewal

On March 12, 2019, nearly contemporaneously with the Staff issuance of the license amendment, the Staff also approved a twenty-year license renewal for the Seabrook facility.[232] The license amendment applies to the extended operating period granted in the license renewal.[233] The license renewal is not within the scope of this proceeding.[234]

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[228] Id. at PDF 69 (citing Ex. INT018-R, MPR-4153, Revision 3, Seabrook Station-Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction (Sept. 2017) (Enclosure 4 to Letter SBK-18072) [hereinafter Ex. INT018-R, MPR-4153, Rev. 3]; Ex. INT020, MPR-4153, Revision 3, Seabrook Station-Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction (Sept. 2017) (Enclosure 6 to Letter SBK-18072) [hereinafter Ex. INT020, MPR-4153, Rev. 3] (non-public)).

[229] Ex. NER001, MPR Testimony at 129; Tr. at 1135–37 (Carley).

[230] Ex. INT024, Final SE at PDF 68; 10 C.F.R. pt. 50, app. B, Criterion XVI.

[231] Ex. NRC001-R, Staff Testimony at 51–52.

[232] NextEra Energy Seabrook, LLC; Seabrook Station, Unit No. 1, 84 Fed. Reg. 9563, 9563–64 (Mar. 12, 2019).

[233] See generally Ex. INT010, Original LAR.

[234] CLI-19-7, 90 NRC at 9; see infra Part VII.B.

V. Summary of the Parties' Statements of Position

A. C-10

On June 10, 2019, C-10 filed its Initial Statement of Position (SOP).[235] In relying on testimony by its expert Dr. Saouma, C-10 disagreed with both the testing and analytical methods conducted by NextEra.[236] C-10 requested that the Board invalidate the LAR and so the associated license amendment and refer the matter to the Commission to determine whether the license renewal should likewise be invalidated.[237] C-10 argued NextEra's ASR analysis is lacking in several main areas, specifically that: (1) NextEra did not use concrete that was representative of Seabrook concrete in the LSTP;[238] (2) NextEra did not use specimen dimensions, loads, and boundary conditions representative of Seabrook;[239] (3) "NextEra failed to explain the impact of the large horizontal crack that occurred before the shear test on results";[240] and (4) NextEra relied on faulty assumptions about ASR, such as confusing material strength with structural strength.[241] C-10 asserted that these issues render NextEra's finite element analysis (FEA)[242] unreliable and undermine the adequacy of parameters used in the

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[235] [C-10] Initial Statement of Position on C-10's Contentions Regarding NextEra's Program for Managing ASR at Seabrook Station Nuclear Power Plant (June 10, 2019) [hereinafter C-10 Initial SOP].

[236] Id. at 1–2.

[237] Id. at 2, 13–14.

[238] Id. at 10.

[239] Id.

[240] Id.

[241] Id. at 11.

[242] The FEA is a computational model that includes various elements to "collectively . . . simulate the structural geometry, stiffness, and mass" of the desired structure where one can add loads (i.e., demands), such as gravity, wind, or ASR, to the FEA to measure structural responses. See Ex. NER004, SGH Testimony at 39–40; see supra notes 49–54 and accompanying text.

ASR expansion monitoring program.[243] Moreover, C-10 suggested that NextEra applied an overly simplistic analytical method to the LSTP data that did not account for the complexities of ASR[244] and that NextEra failed to seek peer review by ASR experts.[245] In sum, C-10 argued NextEra failed to satisfy its burden to show the LAR complies with all applicable legal requirements.[246]

C-10 filed a Rebuttal SOP on August 23, 2019,[247] which included additional rebuttal testimony by Dr. Saouma.[248] C-10 emphasized Dr. Saouma is the only expert witness to testify with "extensive scientific and engineering experience in the study of ASR," and asserted that the Staff and NextEra lacked sufficient expertise and independent peer review by ASR experts.[249] As such, C-10 argued, the Board should give the expert testimony of Dr. Saouma greater weight than the other experts.[250]

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[243] C-10 Initial SOP at 11.

[244] Id.

[245] Id. at 12.

[246] Id. at 12–13.

[247] [C-10] Rebuttal Statement of Position on C-10's Contentions Regarding NextEra's Program for Managing ASR at Seabrook Station Nuclear Power Plant (Aug. 23, 2019) [hereinafter C-10 Rebuttal SOP].

[248] Ex. INT028, Rebuttal Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant [hereinafter Ex. INT028, Dr. Saouma Rebuttal Testimony] (non-public). A non-proprietary version of Ex. INT028, Dr. Saouma Rebuttal Testimony, was filed by C-10 on September 11, 2019. See Ex. INT032, Rebuttal Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant [hereinafter Ex. INT032, Dr. Saouma Rebuttal Testimony].

[249] C-10 Rebuttal SOP at 3.

[250] Id.

B. NextEra

On July 24, 2019, NextEra submitted its SOP,[251] arguing the LAR provides reasonable assurance and complies with applicable regulations.[252] Specifically, NextEra asserted that the LSTP yielded data representative of ASR-affected concrete at Seabrook;[253] the SMP is fully supported, provides reasonable assurance, and complies with applicable regulations;[254] and the Structural Evaluation Methodology (SEM) is adequate.[255]

As a threshold matter, NextEra argued C-10 failed to meet its initial burden of moving forward with sufficient evidence to show a deficiency in the LAR.[256] NextEra proffered several supporting arguments: (1) Dr. Saouma "either abandon[ed] or contradict[ed] nearly every argument advanced in the original Petition"; (2) Dr. Saouma focuse[d] on new challenges to the LAR not contemplated in the original Petition; (3) Dr. Saouma failed to identify an issue in the LAR regarding representativeness; (4) C-10 is incorrect in arguing the LAR is not peer reviewed; (5) NextEra's use of linear elastic code-based analysis is appropriate, and C-10 failed to identify a material deficiency in its application; (6) Dr. Saouma failed to fully review the LAR and its complete technical basis; and (7) C-10 seeks to impose requirements beyond those mandated by the reasonable assurance standard.[257] NextEra further argued that C-10 failed to "acknowledge the legal and regulatory standards applicable to the LAR—much less demonstrate how the LAR somehow fails to satisfy those standards."[258]

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[251] [NextEra]'s Statement of Position (July 24, 2019).

[252] Id. at 20–28.

[253] Id. at 20–24.

[254] Id. at 24–26.

[255] Id. at 26–28.

[256] Id. at 2.

[257] Id. at 3–4, 5 (emphasis omitted).

[258] Id. at 4–5 (emphasis omitted).

NextEra summarized the qualifications of its experts[259] and asserted that substantial information in the record demonstrates reasonable assurance that Seabrook Station will not endanger the health and safety of the public.[260] Further, NextEra stated that Seabrook would conduct its authorized activities in compliance with applicable regulations.[261] Finally, NextEra concluded that the issuance of the LAR is not inimical to the common defense and security.[262] In rebuttal of C-10's critiques,[263] NextEra alleged that while many of C-10's arguments do not relate to representativeness, those that do result from a disregard of technical documents or a misunderstanding of the programmatic details and/or objectives of the LSTP.[264] NextEra concluded by stating its program addressing ASR "is robust, conservative, technically justified, and satisfies the reasonable assurance standard."[265] In sum, NextEra asserted that the Board should resolve the reformulated contention in its favor.[266]

C. NRC Staff

On July 24, 2019, the Staff submitted its SOP.[267] The Staff found that the LSTP provides reasonable assurance that its data is representative and/or bounding of the progression of ASR at Seabrook.[268] Further, the Staff found that NextEra appropriately used the LSTP data to develop the ASR expansion monitoring program.[269] The Staff maintained that

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[259] Id. at 10–14.

[260] Id. at 9.

[261] Id.

[262] Id. (citing 10 C.F.R. §§ 50.92, 50.57(a)(3), (6)).

[263] Id. at 5, 31.

[264] Id. at 31–32.

[265] Id. at 37.

[266] Id. at 37–38.

[267] NRC Staff Initial Written Statement of Position (July 24, 2019) [hereinafter NRC Staff SOP].

[268] Id. at 1.

[269] Id.

"the Board should uphold the Staff's determination that NextEra has provided reasonable assurance that, with the license amendment, as conditioned, Seabrook will continue to meet NRC requirements."[270]

According to the Staff, it reviewed each component of the LSTP, finding each one to be representative and/or bounding of the concrete at Seabrook.[271] The Staff further determined that the concrete of the test specimens reasonably reflected the properties of the concrete in Seabrook structures.[272] The Staff also found that the Shear Test Program and Reinforcement Anchorage Test Program were representative and/or bounding of Seabrook structures.[273] The Staff concluded that NextEra appropriately used data from the LSTP to develop the Expansion Monitoring Program.[274] The Staff concluded that NextEra's approach to establishing the expansion limits by testing ASR at levels above those found at Seabrook, which resulted in a finding of no reduction in structural capacity, was conservative and appropriate.[275]

The Staff provided a rebuttal to each of C-10's arguments. First, the Staff recognized that the concrete aggregate used for the LSTP is not identical.[276] Nonetheless, it argued that the concrete used in the LSTP "was sufficiently representative and/or bounding of the concrete at Seabrook such that the results of the LSTP could reasonably be applied to Seabrook."[277] The Staff also noted that the concrete used in the LSTP had similar specifications to Seabrook

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[270] Id. at 2.

[271] Id. at 33.

[272] Id. at 35 ("For example, the concrete mix design for the specimens was based on specifications used at Seabrook (e.g., compressive strength, coarse aggregate gradation and type, water-to-cement ratio, cement type, aggregate proportions) and, in part, included constituents obtained from sources similar to those used during the construction of the plant.").

[273] Id. at 36–39.

[274] Id. at 43–45.

[275] Id. at 43–44.

[276] Id. at 46.

[277] Id. (citing Ex. NRC001-R, Staff Testimony at 50–52).

concrete and used materials similar to the original materials.[278] Additionally, the Staff disputed C-10's argument that a different form of testing should have been done, stating that such an argument is outside the scope of the proceeding as the Staff's review is limited to a finding of reasonable assurance of the selected methods.[279] Further, the Staff argued that C-10 failed to specify how the lack of accelerated expansion tests presents a safety concern.[280] The Staff likewise contended that C-10's arguments regarding a lack of representativeness in the LSTP are not persuasive.[281] The Staff concluded by maintaining that none of the arguments presented by C-10 credibly dispute the Staff's determination that "NextEra has provided reasonable assurance that, with the license amendment, as conditioned, Seabrook will continue to meet NRC requirements."[282]

VI. Witnesses

A. Qualifications of Witnesses

1. C-10's Expert Witness

Dr. Victor E. Saouma testified as the sole expert for C-10. Dr. Saouma has a Ph.D. in Civil Engineering from Cornell University and is a Professor of Civil Engineering at the University of Colorado in Boulder.[283] Dr. Saouma is an experienced ASR researcher with over fifteen years of experience in various ASR disciplines. His research has encompassed material and structural testing, theoretical and computational modeling, experimental dynamics, fracture mechanics, and risk-based numerical assessments of bridges, nuclear containment structures,

[278] Id. at 46–47.

[279] Id. at 47–48.

[280] Id. at 48–49.

[281] Id. at 49–51.

[282] Id. at 48.

[283] Ex. INT003, Curriculum Vitae, Dr. Victor E. Saouma at 1–2.

and dams.[284] In addition, Dr. Saouma developed a well-known ASR model, published several books, including one on the numerical modeling of ASR, Numerical Modeling of Alkali Aggregate Reaction (CRC Press 2013), and co-authored dozens of peer-reviewed articles on civil engineering topics, including a 2014 article regarding aging management of ASR at Seabrook.[285] Dr. Saouma serves on numerous scientific organizations, committees, and panels, including current Chair of an International Meeting of Laboratories and Experts of Materials, Construction Systems and Structures committee on Diagnosis and Prognosis of ASR affected Structures.[286] Dr. Saouma also has conducted research for various government agencies and has prepared a four-volume report on ASR for the NRC.[287]

2. NextEra Expert Witnesses

In support of its positions at the evidentiary hearing, NextEra presented eight witnesses: Michael Collins, the Engineering Site Director for Seabrook;[288] John Simons, the General Manager of Projects with MPR;[289] Christopher Bagley, a Technical Lead and Project Manager

[284] Ex. INT001-R, Pre-filed Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant - Corrected June 20, 2019 at 1 [hereinafter Ex. INT001-R, Dr. Saouma Pre-Filed Testimony] (non-public); Ex. INT027, Pre-Filed Opening Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant - Redacted Version Filed June 26, 2019 at 1 [hereinafter Ex. INT027, Dr. Saouma Pre-Filed Testimony].

[285] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 1–2; Ex. INT033, Saouma, V.E. and Hariri-Ardebili, M.A. (2014). A proposed aging management program for alkali silica reactions in a nuclear power plant. Nuclear Engineering and Design 277, pp. 248-264 (non-public).

[286] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 30–32.

[287] Ex. INT004, Grant Award, Experimental and Numerical Investigation of Alkali Silica Reaction in Nuclear Reactors (2014); Ex. INT005, Experimental and Numerical Investigation of Alkali Silica Reaction in Nuclear Reactors, Grant No. NRC-HQ-60-14-G-0010, Oct. 2014 - Dec. 2017 ($703,197).

[288] Ex. NER006, Michael Collins Biography.

[289] Ex. NER008, John Simons Curriculum Vitae.

with MPR;[290] Dr. Oguzhan Bayrak, a Professor of Civil, Architectural, and Environmental Engineering;[291] Edward Carley, the current License Renewal Supervisor for Seabrook,[292] Dr. Said Bolourchi, a Senior Principal the Engineering Mechanics and Infrastructure practice of Simpson Gumpertz & Heger Inc. (SGH);[293] Glenn Bell, a Senior Principal and the Quality Assurance officer for SGH;[294] and Matthew Sherman, a Senior Principal with SGH.[295]

Michael Collins is the Engineering Site Director for Seabrook and has more than thirty-eight years of professional experience in the nuclear power industry.[296] In addition, Mr. Collins is responsible for the engineering management and technical oversight of ASR-related activities at Seabrook and is knowledgeable about the initial detection of ASR at Seabrook, the development of the LAR, and the execution of the SMP.[297]

John Simons is the General Manager of Projects with MPR and has more than thirty-two years of professional experience in the nuclear industry.[298] Mr. Simons has first-hand knowledge of NextEra's multi-year program to evaluate ASR at Seabrook, including the development and application of the LSTP into the SMP.[299]

Christopher Bagley is a Technical Lead and Project Manager at MPR with more than fifteen years of professional experience in the nuclear power industry.[300] Mr. Bagley serves as

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[290] Ex. NER009, Christopher Bagley Curriculum Vitae.

[291] Ex. NER010, Dr. Oguzhan Bayrak Curriculum Vitae.

[292] Ex. NER011, Edward Carley Resume.

[293] Ex. NER031, [Dr.] Said Bolourchi Curriculum Vitae.

[294] Ex. NER032, Glenn Bell Curriculum Vitae.

[295] Ex. NER033, Matthew Sherman Curriculum Vitae.

[296] Ex. NER006, Michael Collins Biography; Ex. NER001, MPR Testimony at 1–3.

[297] Ex. NER001, MPR Testimony at 3.

[298] Ex. NER008, John Simons Curriculum Vitae; Ex. NER001, MPR Testimony at 4.

[299] Ex. NER001, MPR Testimony at 4–5.

[300] Ex. NER009, Christopher Bagley Curriculum Vitae; Ex. NER001, MPR Testimony at 6.

a Supervisory Engineer and has first-hand knowledge of NextEra's program to evaluate ASR at Seabrook.[301] In addition, he worked on the development and execution of the LSTP, the application of LSTP results to Seabrook, and the methodology for calculating existing ASR expansion.[302] Lastly, he prepared reports for the Electric Power Research Institute (EPRI) on addressing ASR in concrete at nuclear plants.[303]

Dr. Oguzhan Bayrak is a Licensed Professional Engineer and a professor at the University of Texas-Austin's Cockrell School of Engineering, with more than twenty years of professional experience in structural engineering and over thirteen years of experience related to ASR.[304] Dr. Bayrak has specifically focused on the behavior, analysis, and design of reinforced and prestressed concrete structures, the evaluation of structures in distress, and earthquake engineering.[305] Dr. Bayrak is an ACI Fellow, a member of the Precast/Prestressed Concrete Institute, and Chair of the Federation Internationale du Beton, also known as the International Federation for Structural Concrete.[306]

Dr. Bayrak led the LSTP at the FSEL[307] and was the principal investigator and research supervisor for all LSTP efforts conducted at FSEL.[308] Prior to conducting the LSTP, Dr. Bayrak completed four large-scale test programs with field applications and structural assessments for the Texas Department of Transportation.[309]

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[301] Ex. NER001, MPR Testimony at 6–7.

[302] Id. at 7–8; Ex. NER009, Christopher Bagley Curriculum Vitae at 1.

[303] Ex. NER001, MPR Testimony at 7–8.

[304] Ex. NER010, Dr. Oguzhan Bayrak Curriculum Vitae; Tr. at 805 (Bayrak).

[305] Ex. NER001, MPR Testimony at 9.

[306] Id. at 8–10.

[307] Id. at 8–11.

[308] Id. at 11.

[309] Id. at 10.

Edward Carley serves as a Nuclear Engineering Supervisor for Seabrook and has more than thirty-eight years of professional experience in the nuclear power industry.[310] Mr. Carley oversaw NextEra's development and regulatory review of the LAR, including the development of the overall approach to the aging management program for ASR in the SMP.[311]

Dr. Said Bolourchi is a Licensed Professional Engineer and a Senior Principal at SGH.[312] Dr. Bolourchi has more than forty years of professional experience in the nuclear power industry and has experience related to seismic evaluations of nuclear structures, non-linear modeling, and analysis of highly complex structural loading.[313] He is the Principal-in-Charge for all SGH projects associated with the evaluation of seismic Category I structures at Seabrook.[314]

Glenn Bell is a Senior Principal at SGH and a Licensed Professional Engineer.[315] Mr. Bell has more than forty-four years of professional experience in the structural engineering industry.[316] Previously, Mr. Bell was the CEO of SGH and served on its Board of Directors as Chair.[317] In addition, he is the President-elect of the Structural Engineering Institute and a Board Trustee of the Institution of Structural Engineers (ISE).[318] Lastly, Mr. Bell has first-hand knowledge of the construction of the SEM, supervising the development of ASR load factors for the SEM and the structural analysis for the Containment Building at Seabrook.[319]

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[310] Ex. NER011, Edward Carley Resume; Ex. NER001, MPR Testimony at 12–13.

[311] Ex. NER001, MPR Testimony at 13.

[312] Ex. NER031, [Dr.] Said Bolourchi Curriculum Vitae; Ex. NER004, SGH Testimony at 1–5.

[313] Ex. NER004, SGH Testimony at 2–5; Tr. at 363–64, 1105 (Bolourchi).

[314] Ex. NER031, [Dr]. Said Bolourchi Curriculum Vitae.

[315] Ex. NER032, Glenn Bell Curriculum Vitae; Ex. NER004, SGH Testimony at 5–6.

[316] Ex. NER032, Glenn Bell Curriculum Vitae; Ex. NER004, SGH Testimony at 5.

[317] Ex. NER032, Glenn Bell Curriculum Vitae.

[318] Ex. NER004, SGH Testimony at 6.

[319] Id. at 5.

Matthew Sherman is a Senior Principal at SGH and a Licensed Professional Engineer.[320] Mr. Sherman has twenty years of professional experience in both the civil and structural engineering industry, with a focus on construction materials, repair and rehabilitation, and testing.[321] Mr. Sherman is a Fellow at both the ACI and the International Concrete Repair Institute.[322] He has first-hand knowledge of the development of the SEM and oversaw the fieldwork, testing, and petrographic studies associated with the structural evaluation of Seabrook structures affected by ASR, including the application of structural monitoring parameters and frequency of monitoring included as inputs to the SMP.[323]

3. NRC Staff Expert Witnesses

The Staff presented four witnesses: Angela Buford, a Structural Engineer in NRC's Office of Nuclear Reactor Regulation (NRR), Division of Engineering Structural Engineering Branch;[324] Bryce Lehman, a Civil Engineer in NRR;[325] Dr. George Thomas, a Senior Structural Engineer in NRR;[326] and Jacob Philip, a Senior Geotechnical Civil Engineer in NRC's Division of Engineering, Office of Nuclear Regulatory Research (RES).[327]

Angela Buford is a Licensed Professional Engineer with over fifteen years of engineering experience.[328] Ms. Buford has worked for the NRC as a structural engineer and technical reviewer in NRR since 2010.[329] Ms. Buford led a team of structural engineers in evaluating ASR

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[320] Ex. NER033, Matthew Sherman Curriculum Vitae; Ex. NER004, SGH Testimony at 7–8.

[321] Ex. NER033, Matthew Sherman Curriculum Vitae; Ex. NER004, SGH Testimony at 7.

[322] Ex. NER004, SGH Testimony at 7.

[323] Id. at 8–9.

[324] Ex. NRC002, Statement of Professional Qualifications of Angela Buford.

[325] Ex. NRC003, Statement of Professional Qualifications of Bryce Lehman.

[326] Ex. NRC004, Statement of Professional Qualifications of [Dr.] George Thomas.

[327] Ex. NRC005, Jacob [Philip] Testimony.

[328] Ex. NRC002, Angela Buford Curriculum Vitae; Ex. NRC001-R, Staff Testimony at 1.

[329] Ex. NRC002, Angela Buford Curriculum Vitae.

at Seabrook in the context of the facility's license renewal.[330] Ms. Buford has also worked on three subsequent license renewal audits that addressed several novel technical issues, including irradiation of concrete and steel structures.[331] Additionally, she led an international team of civil and structural engineers in revising the International Generic Aging Lessons Learned report.[332] She has performed numerous briefings on a variety of technical and programmatic topics for congressional staff, the NRC Chairman, the NRC Executive Director for Operations, NRC office directors, the ACRS, NRR division management, the public, and peers.[333]

Bryce Lehman is an NRR civil and structural engineer with fifteen years of structural experience, more than ten of which are in nuclear power.[334] Mr. Lehman has performed "technical, safety, and regulatory compliance reviews of license amendment requests and relief requests related to structures, including reactor containment buildings."[335] Moreover, he has conducted structural reviews of multiple license renewal applications.[336] Previously, as an employee of Structural Repair Group, Mr. Lehman inspected concrete structures such as condominiums and parking garages to identify structural degradation.[337] As a former Design Engineer for Ralph Whitehead Associates, Inc., Mr. Lehman surveyed and inspected railroad bridges.[338]

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[330] Id.

[331] Id.

[332] Id.

[333] Id.

[334] Ex. NRC003, Bryce Lehman Curriculum Vitae; Ex. NRC001-R, Staff Testimony at 1.

[335] Ex. NRC003, Bryce Lehman Curriculum Vitae.

[336] Id.

[337] Id.

[338] Id.

Dr. George Thomas is a Licensed Professional Engineer and a Senior Structural Engineer in the NRR Division of Engineering.[339] Dr. Thomas has over thirty years of experience as a structural engineer in regulatory work, the private sector, and research.[340] Additionally, he has more than twenty-three years of experience in the United States nuclear industry with both NRC and Bechtel Power Corporation.[341] Dr. Thomas serves as the NRC voting member on the Joint American Society of Mechanical Engineers-American Concrete Institute (ASME-ACI) Code Committee for Concrete Containments.[342] In addition, he has made contributions to the NRC's codes and standards activities, as well as regulatory guidance development related to analysis, design, in-service inspection, and aging management of nuclear safety-related reinforced concrete structures.[343]

Jacob Philip is a Licensed Professional Engineer with fifty years of experience and currently is a Senior Geotechnical Engineer in the NRC's Office of Nuclear Regulatory Research (RES), Division of Engineering, Structural, Geotechnical, and Seismic Engineering Branch.[344] Mr. Philip has been with the NRC for almost thirty-nine years and has authored several safety evaluation reports for existing nuclear reactors when he was in NRR.[345] For the last seven years, Mr. Philip has developed and managed research on ASR at the NRC and is the project manager for ASR research at the National Institute of Standards and Technology.[346]

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[339] Ex. NRC004, [Dr.] George Thomas Curriculum Vitae; Ex. NRC001-R, Staff Testimony at 1.

[340] Ex. NRC004, [Dr.] George Thomas Curriculum Vitae.

[341] Id.

[342] Id.

[343] Id.

[344] Ex. NRC006, Statement of Professional Qualifications of Jacob Philip; Ex. NRC005, Jacob [Philip] Testimony at 1.

[345] Ex. NRC006, Statement of Professional Qualifications of Jacob Philip.

[346] Id.

B. Admissibility/Weight of Expert Testimony

In evaluating the various issues in dispute, the Board must assign the appropriate weight to the testimony of each expert witness according to the witness's level of expertise.[347] The key qualifications of all the main expert witnesses are enumerated above.

During the hearing, the Board heard from one expert witness from C-10; a multitude of expert witnesses from NextEra and its contractors who were involved in planning, executing and submitting the LAR; and four expert Staff witnesses involved in various aspects of the review and approval of the LAR. At the beginning of the hearing, the Board inquired whether any party objected to the testimony of any expert based on a lack of qualifications. No such objection was raised.[348]

Nevertheless, in its Proposed Findings submitted after the evidentiary hearing, NextEra challenged the qualifications of C-10's expert witness, Dr. Saouma, and the bases of his opinions.[349] NextEra would have the Board find that Dr. Saouma is qualified only to provide expert testimony on the topics of ASR and structural engineering, testing, and analysis, and that he is not qualified to testify on the topics of anchors and reinforcement anchorage, NRC licensing and regulation, knowledge of Seabrook's seismic Category I structures, the LAR and its various components, the NRC's oversight of NextEra's ASR-related activities and review of the LAR, and engineering practice.[350]

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[347] See Catawba, CLI-04-21, 60 NRC at 31; Shearon Harris, LBP-01-9, 53 NRC at 251 (reasoning that licensing boards should give expert testimony "due weight" proportionate to their expertise); see also Burkhart v. Wash. Metro. Transit Auth., 112 F.3d 1207, 1212 (D.C. Cir. 1997) (lack of specialization by an expert witness does not disqualify the expert but goes to the weight of the expert's testimony).

[348] Tr. at 260–61.

[349] See NextEra's Proposed Findings of Fact and Conclusions of Law at 32.

[350] Id.

We recognize that Dr. Saouma disavowed any expertise regarding anchors,[351] but that is of no relevance here because C-10 has not made any claim concerning anchors.[352] We also agree that Dr. Saouma is not an expert on NRC regulations, but he was not offered as an expert on the regulations.[353]

We reject the remainder of NextEra's objections. In general, an expert may be qualified to testify based on knowledge, skill, experience, training, or education.[354] Although Dr. Saouma is not a Licensed Professional Engineer, he is a preeminent researcher in the science of ASR degradation in concrete.[355] His testimony[356] and list of qualifications and experience[357] reveals that he has been a technical consultant on numerous projects related to the management of ASR. We therefore find him qualified to testify regarding sound engineering practice in the management of ASR.[358]

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[351] Tr. at 674 (Saouma) ("I confess full ignorance about anchors."); Tr. at 675 (Saouma) (noting he is not "in a position" to present any testimony to contradict NextEra's evidence regarding the LSTP anchor testing); Tr. at 435 (Bayrak) (noting that Dr. Saouma confirmed reinforcement anchorage was "outside his area of expertise"); Tr. at 266 (Saouma).

[352] See generally C-10 Initial SOP; C-10 Rebuttal SOP.

[353] It is the duty of the Board to interpret statutes and regulations, subject to Commission review. Counsel may argue how the law should be interpreted, but in general that is not a proper subject of expert testimony. See Tenn. Valley Auth. (Clinch River Nuclear Site), LBP-18-4, 88 NRC 55, 67 n.70 (2018).

[354] See Duke Power Co. (William B. McGuire Nuclear Station, Units 1 & 2), ALAB-669, 15 NRC 453, 475 (1982); Fed. R. Evid. 702.

[355] See Ex. INT003, Curriculum Vitae, Dr. Victor E. Saouma.

[356] See generally Ex. INT001-R, Dr. Saouma Pre-Filed Testimony (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony; Ex. INT028, Dr. Saouma Rebuttal Testimony (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony.

[357] See Ex. INT003, Curriculum Vitae, Dr. Victor E. Saouma.

[358] See Meridian Mfg., Inc. v. C&B Mfg., Inc., 340 F. Supp. 3d 808, 831 (N.D. Iowa 2018) (holding expert witness qualified to testify as to the obviousness of design and validity of patent claims, despite not being a licensed professional engineer, where expert had associate degree, bachelor of science degree, and master of science degree in mechanical engineering, as well as 38 years of experience in mechanical engineering and industrial design, and was named inventor of subject matter covered by six patents).

We are also not persuaded by the argument that Dr. Saouma's review of the extensive documentation in this case was insufficient to allow him to express opinions regarding the impact of ASR on Seabrook structures. "As a general rule, questions relating to the bases and sources of an expert's opinion affect the weight to be assigned that opinion rather than its admissibility and should be left for the [trier of fact's] consideration."[359] Dr. Saouma's written testimony explains the documentation he reviewed.[360] He also participated in the plant tour where he had the opportunity to observe the ASR-induced degradation of various Seabrook structures, including the Containment Enclosure Building (CEB). This is a sufficient basis for his expert opinions. To the extent NextEra identified specific relevant documentation that Dr. Saouma failed to review, that goes to the weight to be afforded his testimony, not its admissibility.

Although it has not directly challenged the qualifications of any particular NextEra or Staff expert witness, C-10 generally challenged the expertise retained by NextEra to develop, and of the Staff to review, the LAR.[361] Specifically, C-10 criticized the lack of adequate ASR expertise of those involved in generating and reviewing the LAR.[362] Those parties include employees of NextEra itself, as well as the FSEL at the University of Texas, MPR, and SGH.[363]

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[359] Viterbo v. Dow Chemical Co., 826 F.2d 420, 422 (5th Cir. 1987); accord Goodrich Ave., LLC v. Sw. Water Co., 891 F. Supp. 2d 1364, 1382 (M.D. Ga. 2012) (holding that even though wood scientist expert witness never personally observed damage to wood floor in warehouse, he was qualified to testify, for purposes of negligence and trespass trial against water company, as to the damage floor had sustained; in forming his opinion, witness was permitted to consult other sources about the condition and nature of the flooring, and any weaknesses in his testimony went to its weight, rather than its admissibility); see supra note 200 and accompanying text.

[360] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 3–5.

[361] Id. at 5, 7–9, 34–36; Ex. INT032, Dr. Saouma Rebuttal Testimony at 4, 7–8, 10–12.

[362] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5, 7–9, 36; Ex. INT032, Dr. Saouma Rebuttal Testimony at 4, 7–8, 11–12, 43–44.

[363] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 7–9; Ex. INT032, Dr. Saouma Rebuttal Testimony at 7–8 (explaining his opinion that NextEra witnesses have limited expertise on this issue). NextEra witnesses Michael Collins, John Simons, Christopher Bagley, Dr. Oguzhan

Moreover, C-10 criticized the lack of ASR expertise of those involved in reviewing the LAR, including the Staff and its contractors, and the ACRS.[364] C-10 emphasized the importance of seeking the expertise of leading researchers in the absence of established standards for evaluating the hazards posed by ASR.[365] Thus, C-10 grounded its criticism in the need to take full advantage of the scientific research that has been performed in studying ASR degradation in concrete.

These C-10 challenges are beyond the scope of this proceeding because no admitted contention makes such a challenge. The sole province of the Board in this decision, particularly after hearing no valid objections to any experts' qualifications,[366] is to weigh the expert testimony before us.[367] Insofar as C-10 challenged the credentials of testifying experts, any gaps in testimony will go to the weight of expert testimony, not its admissibility.[368] We will not, however, consider challenges to the experts retained by NextEra to develop, and the Staff to review, the LAR.

VII. Motions in Limine

In our June 7 and September 20, 2019 orders issued in response to NextEra's first and second Motions in Limine,[369] respectively, we stated that we would defer our ruling on the

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Bayrak, and Edward Carley are all MPR employees. See generally Ex. NER001, MPR Testimony.

[364] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5, 36; Ex. INT032, Dr. Saouma Rebuttal Testimony at 7–8, 11–12.

[365] Ex. INT032, Dr. Saouma Rebuttal Testimony at 7 ("[N]one of NextEra's or the NRC Staff's witnesses ha[ve] demonstrated previous involvement in the specific study of ASR . . . . The absence of such scientific expertise throughout the investigation and LAR has severely handicapped the LAR process.").

[366] Tr. at 260–61.

[367] See supra notes 199–204 and accompanying text.

[368] See supra note 200 and accompanying text.

[369] See NextEra's Motion in Limine to Exclude Testimony and Exhibits Regarding Structure Deformation Monitoring (Apr. 23, 2019) [hereinafter NextEra MIL 1]; NextEra's Motion in Limine

disputed portions of C-10's pre-filed testimony until we had available the full evidentiary record.[370] We now resolve those issues.

In its first Motion in Limine, NextEra argued that the scope of the reformulated contention is limited to the representativeness of the LSTP and certain aspects of the ASR Expansion Monitoring program.[371] NextEra sought to preemptively exclude all allegedly irrelevant and out of scope materials.[372] In its second Motion in Limine, NextEra moved to strike certain portions of C-10's testimony and exhibits deemed "irrelevant, immaterial, unduly cumulative, [and] beyond the scope" of the reformulated contention.[373] NextEra disputed several portions of C-10's testimony, including the topics of steel corrosion, testing to the point of failure/the use of alternative methodologies, license renewal, peer review, mineralogy, scaling/boundary conditions, the structural deformation program, design basis loads/load factors, and improper rebuttal testimony.[374] The Staff generally agreed with NextEra's motion.[375]

In this section, we resolve several of NextEra's objections. The remaining rulings on its Motion in Limine objections are addressed below with the Board's analysis of the specific issue to which the objection pertains.

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to Strike or Exclude Portions of C-10's Testimony and Exhibits (Sept. 9, 2019) [hereinafter NextEra MIL 2].

[370] Licensing Board Order (Deferring Ruling on NextEra's Second Motion in Limine) (Sept. 20, 2019) at 2 (unpublished); Licensing Board Order (Ruling on NextEra's Motion in Limine) (June 7, 2019) at 1 (unpublished).

[371] NextEra MIL 1 at 10.

[372] Id. at 11.

[373] NextEra MIL 2 at 1.

[374] See generally NextEra MIL 2.

[375] NRC Staff's Ans. to NextEra's Motion in Limine (Sept. 18, 2019) at 1 n.2 [hereinafter Staff Ans. to MIL 2].

A. Proper Scope of Rebuttal Testimony

NextEra argued that several sections of Dr. Saouma's rebuttal testimony[376] are procedurally improper as they either consist of entirely new arguments, fail to rebut testimony, or impermissibly bolster existing arguments.[377] NextEra cited authority purporting to establish the scope of rebuttal testimony in licensing board proceedings, stating rebuttal testimony is limited "to new or surprise material"[378] and may "not advance any new affirmative claims or arguments that should have been, but were not, included in the party's previously filed initial written statement."[379] The Staff agreed with this argument,[380] while C-10 did not.[381] For the reasons discussed below, we agree with C-10 and decline to apply that strict interpretation of rebuttal testimony to Dr. Saouma's rebuttal testimony, summary of rebuttal testimony, and

[376] See Ex. INT028, Dr. Saouma Rebuttal Testimony §§ A.2, A.3, A.9, A.10, A.11, A.14, B.3, B.4, B.6, D.1.1, D.1.2, D.3.2, D.4.1, D.4.2, D.6.1, D.7.1, D.7.2, D.7.4, D.8.2, D.8.3, D.9.1, D.9.2, D.9.3, D.9.4 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony §§ A.2, A.3, A.9, A.10, A.11, A.14, B.3, B.4, B.6, D.1.1, D.1.2, D.3.2, D.4.1, D.4.2, D.6.1, D.7.1, D.7.2, D.7.4, D.8.2, D.8.3, D.9.1, D.9.2, D.9.3, D.9.4; Ex. INT029, Summary of Rebuttal Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant §§ A.2, A.3, A.9, A.10, A.11, A.14, B.3, B.4, B.6 [hereinafter Ex. INT029, Summary of Dr. Saouma Rebuttal Testimony]; Ex. INT030-R, [Supplemental] Rebuttal Testimony of Victor E. Saouma, Ph.D Regarding Scientific Evaluation of NextEra's Aging Management Program for Alkali-Silica Reaction at the Seabrook Nuclear Power Plant (Revised) [hereinafter Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony].

[377] NextEra MIL 2 at 27–31.

[378] Rockwell Int'l Corp. Rocketdyne Div. (Special Material License Number SNM-21), LBP-89-27, 30 NRC 265, 269 (1989) (permitting rebuttal testimony "only with respect to new or surprise material" included in the opposing party's testimony).

[379] Progress Energy Fla., Inc. (Levy County Nuclear Power Plant, Units 1 & 2), LBP-09-22, 70 NRC 640, 655 (2009) ("Being in the nature of rebuttal, the response, rebuttal testimony, and rebuttal exhibits are not to advance any new affirmative claims or arguments that should have been, but were not, included in the party's previously filed initial written statement.").

[380] Staff Ans. to MIL 2 at 5.

[381] [C-10's] Opposition to NextEra's Second Motion in Limine (Sept. 19, 2019) at 19–20 [hereinafter C-10 Opp. to MIL 2].

supplemental rebuttal testimony.[382] However, a few sections of those exhibits, as noted below, fail altogether to meet the requirements of rebuttal testimony in 10 C.F.R. § 2.1207(a)(2). Therefore, NextEra's Motion in Limine with respect to impermissible rebuttal testimony is granted in part, denied in part.

Under 10 C.F.R. § 2.319, a licensing board has the power to "[r]estrict irrelevant, immaterial, unreliable, duplicative or cumulative evidence and/or arguments."[383] Commission precedent indicates that "a licensing board normally has considerable discretion in making evidentiary rulings."[384] In addition, although licensing boards may refer to the Federal Rules of Evidence for guidance,[385] we are not bound by them.[386] Moreover, licensing boards do not require strict rules of evidence to prevent the presentation of unfair and prejudicial evidence to a

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[382] Ex. INT028, Dr. Saouma Rebuttal Testimony (non-public); Ex. INT029, Summary of Dr. Saouma Rebuttal Testimony; Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony; Ex. INT032, Dr. Saouma Rebuttal Testimony.

[383] 10 C.F.R. § 2.319(e).

[384] Catawba, CLI-04-21, 60 NRC at 27.

[385] Although we will determine the propriety of Dr. Saouma's rebuttal testimony within the limits imposed by 10 C.F.R. § 2.1207(a)(2), if we found it necessary to refer to the Federal Rules of Evidence for guidance, Supreme Court precedent supports our holding by recognizing that trial judges have the authority to determine the scope of rebuttal testimony "[w]ithin limits[.]" Geders v. United States, 425 U.S. 80, 86 (1976); id. at 87 ("If truth and fairness are not to be sacrificed, the judge must exert substantial control over the proceedings."). Here, we will determine the propriety of Dr. Saouma's rebuttal testimony within the limits imposed by 10 C.F.R. § 2.1207(a)(2). See Settling Devotional Claimants v. Copyright Royalty Board, 797 F.3d 1106, 1118 (D.C. Cir. 2015) (noting an administrative board "has the discretion" to limit rebuttal testimony, but is not required to do so); see also Angiuoni v. Town of Billerica, 838 F.3d 34, 40 (1st Cir. 2016) ("The wide latitude afforded to trial courts extends to 'determining whether proposed evidence is proper rebuttal.'" (quoting United States v. Thuna, 786 F.2d 437, 444 (1st Cir. 1986))); United States v. Sebaggala, 256 F.3d 59, 66 (1st Cir. 2001) (stating trial courts are permitted "a wide berth in respect to regulating the scope of rebuttal testimony"); Faigin v. Kelly, 184 F.3d 67, 85 (1st Cir. 1999) ("The decision to allow or foreclose rebuttal evidence rests squarely within the informed discretion of the district court."); Fed. R. Evid. 611(a) ("The court shall exercise reasonable control over the mode and order of interrogating witnesses and presenting evidence so as to . . . make the interrogation and presentation effective for the ascertainment of truth . . . .).

[386] S. Cal. Edison Co. (San Onofre Nuclear Generating Station, Units 2 & 3), ALAB-717, 17 NRC 346, 365 n.32 (1983); 10 C.F.R. § 2.319(d).

jury,[387] since, in Subpart L proceedings "[w]ritten prefiled testimony and exhibits are typically submitted well in advance of the evidentiary hearing, and in our most common types of hearings, the licensing boards themselves—not the parties—orally examine the witnesses."[388] Therefore, "the concerns of unfair prejudice and confusion addressed by the Federal Rules of Evidence are rarely at issue when licensing boards rule on the admissibility of evidence in Subpart L proceedings."[389]

To the degree that the regulations governing this Subpart L proceeding define the scope of rebuttal testimony, the delineation is found in 10 C.F.R. § 2.1207(a)(2), which provides that rebuttal testimony must "be directed to the initial statements and testimony of other participants."[390] In addition, presiding officers may issue scheduling orders, delineating rules applicable to the proceeding at hand.[391] We issued several scheduling/case management

[387] See Old Chief v. United States, 519 U.S. 172, 188 n.9 (1997); Fed. R. Evid. 403.

[388] PSEG Power, LLC & PSEG Nuclear, LLC (Early Site Permit Application), LBP-16-4, 83 NRC 187, 210–11 n.171 (2016) (citing 10 C.F.R. § 2.1207).

[389] Licensing Board Order (Ruling on Remaining Evidentiary Objections), Crow Butte Res., Inc. (License Renewal for the In Situ Leach Facility, Crawford, Nebraska), No. 40-8943 (Dec. 6, 2016) at 2 (citing PSEG Power, LBP-16-4, 83 NRC at 210–11 n.171) (unpublished).

[390] 10 C.F.R. § 2.1207(a)(2).

[391] Id. § 2.332.

orders throughout this case but declined to define the scope of rebuttal testimony,[392] in accord with a presiding officer's broad authority to regulate the conduct of proceedings.[393]

NextEra cited four licensing board scheduling orders, two of which are unpublished, that purport to support its narrow definition of rebuttal testimony.[394] However, those licensing board scheduling orders, which at most provide persuasive authority,[395] are merely procedural orders that prescribe the rules for a specific proceeding.[396] Contrary to NextEra's argument, procedural scheduling orders do not provide binding precedent in managing the conduct of proceedings or making evidentiary determinations. We therefore decline to apply specific

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[392] See Order Closing the Hearing Record; Licensing Board Order (Granting C-10's Motion for Leave to File Supplemental Rebuttal Testimony) (Sept. 16, 2019) (unpublished) [hereinafter Order Granting C-10's Motion to File Supplemental Rebuttal Testimony]; Licensing Board Memorandum (Regarding Pre-filed Exhibits) (Aug. 27, 2019) (unpublished); Licensing Board Order (Scheduling Pre-Hearing Teleconference and Providing Instructions) (Aug. 12, 2019) (unpublished); Licensing Board Order (Providing Case Management Instructions) (May 23, 2019) (unpublished); Licensing Board Memorandum and Order (Revised Scheduling Order) (Feb. 15, 2018) (unpublished); Licensing Board Order (Initial Scheduling Order) (Nov. 29, 2017) (unpublished); Licensing Board Order (Identifying hearing procedures, requesting information related to scheduling, and deferring deadlines for production of initial disclosures and the hearing file) (Oct. 26, 2017) (unpublished); Licensing Board Order (Scheduling Oral Argument and Providing Instructions) (June 5, 2017) (unpublished).

[393] 10 C.F.R. § 2.319; Catawba, CLI-04-21, 60 NRC at 27.

[394] NextEra MIL 2 at 8 n.30; Levy, LBP-09-22, 70 NRC at 655; Rockwell, LBP-89-27, 30 NRC at 269; Licensing Board Order (Revised Scheduling Order), Dominion Nuclear N. Anna, LLC (Early Site Permit for North Anna ESP Site), No. 52-008-ESP (Mar. 1, 2006) at 6 (unpublished); Licensing Board Memorandum and Order (Prehearing Conference Call Summary, Case Management Directives, and Final Scheduling Order), AmerGen Energy Co., LLC (License Renewal for Oyster Creek Nuclear Generating Station), No. 50-0219-LR (Apr. 17, 2007) at 5–6 (unpublished).

[395] S. Cal. Edison Co. (San Onofre Nuclear Generating Station, Units 2 & 3), CLI-13-10, 78 NRC 552, 563, 569 n.42 (2013) ("Unreviewed board decisions are not binding on future boards . . . . They may, however, be cited by future litigants as persuasive authority.").

[396] Levy, LBP-09-22, 70 NRC at 640 ("This initial scheduling order is designed to ensure proper case management of this proceeding[.]" (emphasis added)); Rockwell, LBP-89-27, 30 NRC at 266 ("[The Administrative Judge] adopted a schedule for the filings in this case and also stated some ground rules that would apply to those filings." (emphasis added)); see also 10 C.F.R. § 2.332(a)–(c) (noting that the presiding officers may establish scheduling orders specific to the proceeding based on the circumstances of the case).

statements from past scheduling orders when we did not include such language in the scheduling orders of this proceeding. Rather, we will review each disputed section to determine whether it is responsive to initial testimony, as required by 10 C.F.R. § 2.1207(a)(2).

We find most of Dr. Saouma's rebuttal testimony either explicitly responds to the initial testimony of NextEra or the Staff or it is clear from the subject of the testimony that Dr. Saouma is addressing Staff and/or NextEra initial testimony, in accordance with 10 C.F.R. § 2.1207(a)(2). In section D.6.1 of his rebuttal testimony, although Dr. Saouma does not specify the testimony to which he refers, the Board finds that Dr. Saouma's testimony on relative humidity is responsive to NextEra and Staff testimony (specifically, MPR Q214 and Staff Q.36), that questions the saliency of relative humidity.[397] In addition, rebuttal testimony sections D.7.1 and D.7.2 respond to initial testimony by Staff and NextEra witnesses that the shear beam test was conducted appropriately, and it is therefore permissible rebuttal testimony.[398] With the exception of section B.4, each section of rebuttal testimony cited by NextEra in its table contains a reference to the initial testimony to which Dr. Saouma responds.[399] We decline to exclude the rebuttal testimony of sections B.3, D.1.1, D.1.2, D.3.2, D.4.2, D.8.2, D.9.1, D.9.2, D.9.3, and D.9.4 as they are responsive to NextEra or Staff initial testimony in accord with 10 C.F.R. § 2.1207(a)(2).[400] Rebuttal testimony section B.4, however, generally stated that NextEra should

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[397] See Ex. INT028, Dr. Saouma Rebuttal Testimony § D.6.1 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony § D.6.1; Ex. NER001, MPR Testimony at 151–52; Ex. NRC001-R, Staff Testimony at 48–50.

[398] See Ex. INT028, Dr. Saouma Rebuttal Testimony §§ D.7.1, D.7.2 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony §§ D.7.1, D.7.2; Ex. NER001, MPR Testimony at 142–47; Ex. NRC001-R, Staff Testimony at 55–57.

[399] NextEra MIL 2 at 29–31 tbl.

[400] We recognize no specific citations to initial testimony are included for rebuttal testimony section B.3. Id. at 29. However, we find section B.3 responds to initial testimony as it is responsive to Ex. NRC001-R, Staff Testimony at 71–72.

have looked beyond the codes.[401] This section is not responsive to any NextEra or Staff initial testimony but appears to restate a previously proffered argument.[402] Section B.4 is therefore excluded from the record as not directed to any of that initial testimony and as duplicative.

Finally, several sections of Dr. Saouma's rebuttal testimony offer no clear connection to NextEra or Staff initial testimony and must therefore be excluded as failing to fulfill the requirements of 10 C.F.R. § 2.1207(a)(2). For example, in rebuttal testimony section A.2, Dr. Saouma provides more details on his own professional background. This does not appear to address any testimony challenging Dr. Saouma's qualifications but is an attempt to impermissibly bolster his own testimony.[403] Further, rebuttal testimony section A.9, which analogizes ASR to cancer, fails to demonstrate a connection to any NextEra or Staff initial testimony. Section A.9 is thus impermissible rebuttal testimony.[404]

Although we largely denied NextEra's Motion in Limine with regard to Dr. Saouma's rebuttal testimony, we will apply the appropriate evidentiary weight to that testimony to ensure "that [the] hearing[] w[as] fair and produced [an] adequate record[]."[405]

B. License Renewal

NextEra argued that testimony related to license renewal for the Seabrook facility is beyond the scope of this proceeding.[406] We agree. As stated by the Commission, the Staff

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[401] See Ex. INT032, Dr. Saouma Rebuttal Testimony § B.4; Ex. INT029, Summary of Dr. Saouma Rebuttal Testimony § B.4.

[402] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 7, 29–34.

[403] See Ex. INT032, Dr. Saouma Rebuttal Testimony § A.3.

[404] Id. § A.9.

[405] See Statement of Policy on Conduct of Adjudicatory Proceedings, CLI-98-12, 48 NRC 18, 19 (1998); see also N. Anna, ALAB-555, 10 NRC at 26–27. The Board would also like to emphasize that it provided an opportunity for NextEra and the Staff to respond to C-10's supplemental rebuttal testimony, and all rebuttal testimony was filed before the hearing, permitting both parties to address those topics during the hearing in response to Board questions. Order Granting C-10's Motion to File Supplemental Rebuttal Testimony at 4–5.

[406] NextEra MIL 2 at 12–13.

granted that license renewal in a separate proceeding in which C-10 had the opportunity to participate but did not.[407] NextEra's Motion in Limine is granted as to any challenge to the license renewal.[408]

C. Evidence from C-10's Emergency Petition

NextEra seeks to exclude several exhibits C-10 also filed with its Emergency Petition.[409] Specifically, NextEra seeks to exclude Exhibits INT006,[410] INT007,[411] INT008,[412] and INT009[413] on that basis that "all . . . were rejected by the Commission" as beyond the scope of the proceeding.[414] Further, NextEra argued that Ex. INT007 is "largely duplicative of Dr. Saouma's Testimony," and should be excluded as "unduly repetitious, duplicative, and cumulative."[415] C-10, for its part, argued that the Commission did not find all of the supporting documentation for the Emergency Petition beyond the scope of the proceeding.[416] Rather, C-10 argued, the

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[407] CLI-19-7, 90 NRC at 9 n.50. Nor did C-10 meet the requirements for re-opening the license renewal proceeding. Id. at 9.

[408] While the sufficiency of the Seabrook license renewal proceeding is beyond the scope of this proceeding, any modifications or license conditions imposed by this Board will be imposed for the entire period of licensed operation, including under the current licensing term and under the renewed licensing term. See CLI-19-7, 90 NRC at 11 ("[A]ny changes resulting from the review of the LAR will be reflected in the license renewal aging management programs.").

[409] NextEra MIL 2 at 12, 13–14.

[410] Ex. INT006, Declaration of Dr. Victor E. Saouma, Ph.D (Feb. 12, 2019).

[411] Ex. INT007, Saouma, Review of Selected Documents Pertaining to the Structural Evaluation of Seabrook Nuclear Power Plant (Feb. 12, 2019) [hereinafter Ex. INT007, Dr. Saouma Review of Selected Documents] (non-public). Ex. INT031 is the pubic version of Ex. INT007. See Ex. INT031, Saouma, Review of Selected Documents Pertaining to the Structural Evaluation of Seabrook Nuclear Power Plant (Feb. 12, 2019) [hereinafter Ex. INT031, Dr. Saouma Review of Selected Documents].

[412] Ex. INT008, Saouma, Review of Selected Documents Pertaining to the Structural Evaluation of Seabrook Nuclear Power Plant (Feb. 12, 2019).

[413] Ex. INT009, Reply Declaration of Victor E. Saouma, Ph.D (March 1, 2019).

[414] NextEra MIL 2 at 13.

[415] Id.

[416] C-10 Opp. to MIL 2 at 10.

Commission made a general observation that some material submitted was beyond the scope of the proceeding.[417]

We agree with C-10 and decline to exclude the exhibits from C-10's Emergency Petition. As an initial matter, we note that the Commission did not explicitly find that each of the above-listed documents contained information beyond the scope of the proceeding.[418] Rather, the Commission noted generally that "C-10's [emergency] petition raises issues encompassed by its admitted contention, as well as some that are beyond its scope."[419] Therefore, we are not persuaded by NextEra's argument that we should exclude these exhibits as beyond the scope of the proceeding.

In addition, we find that Ex. INT007 is not "unduly repetitious, duplicative, or cumulative,"[420] and in certain instances, the exhibit provided additional probative testimony useful to the Board. Therefore, we decline to exclude it. The Board was neither prejudiced nor burdened in reviewing Ex. INT007. NextEra's Motion in Limine seeking to exclude Exhibits INT006, INT007, INT008, and INT009 is denied.[421]

With these NextEra challenges to the contents of the evidentiary record thus resolved, we turn to our resolution of the merits of the reformulated contention.

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[417] Id.

[418] CLI-19-7, 90 NRC at 6.

[419] Id. at 7.

[420] NextEra MIL 2 at 13.

[421] Although some parts of Exhibits INT006, INT007/INT031, INT008, and INT009 may be immaterial, irrelevant, or unduly cumulative, but using our judgment to review the materials and cite the relevant testimony is more efficient and fairer than a wholesale exclusion of these exhibits. On a practical note, we hardly relied on these exhibits in reaching our decision. Ex. INT007/INT031 is the only one of these exhibits cited in our Initial Decision for its substantive material and is cited in only 8 of over 1,200 footnotes.

VIII. Findings of Fact and Board Analysis of Disputed Issues

A. Representativeness of the LSTP

In the discussion below, we consider two questions regarding the LSTP undertaken for NextEra at the FSEL. First, is the data yielded by the study "representative" of the progression of ASR at Seabrook and second, are the proposed monitoring, acceptance criteria, and inspection intervals adequate to address the progression of ASR. We address several representativeness issues in this section, beginning with concrete mineralogy, test specimen scaling, boundary conditions, and conclude with the effect of reinforcement. In addition, before delving into a substantive discussion of each of these issues, we address the outstanding objections from the Motions in Limine.

1. General Findings Related to Representativeness

ASR is "a [worldwide] known concrete pathology [caused by] chemical reactions between amorphous or poorly crystallized silica contained within reactive aggregates and ions from the pore solution of concrete (hydroxyls, alkalis and calcium ions)."[422] As a result, ASR "leads to progressive destruction of reactive aggregates and precipitation of reaction products called 'gels' whose composition may vary depending on local chemical equilibrium."[423] Concrete structures affected by ASR "exhibit cracking, displacements, structural deformations, pop-outs and reduction in mechanical performances. Service of structures may be severely affected. Gels are usually supposed to be the main cause of the induced swelling and degradations."[424]

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[422] Ex. INT034, S. Poyet et al., "Chemical modelling of Alkali Silica reaction: Influence of the reactive aggregate size distribution" (2006) at 230 [hereinafter Ex. INT034, Poyet et al.] (non-public).

[423] Id. (non-public).

[424] Id. (non-public).

The cracking resulting from ASR is described as "map" or "pattern" cracking and is typically accompanied by dark staining adjacent to cracks on the surface of the structure.[425] One indicator of ASR in degrading concrete is the presence of alkali-silica gel.[426] A visual inspection of the degraded concrete's cracking pattern may also indicate ASR.[427]

"Evaluations of structural adequacy are exercises to determine whether the 'demands' (i.e., load effects) on a structure or its elements exceed the 'capacities' (e.g., strength or stress limits) of the structure or its elements. Methods of determining appropriate demands and capacities are prescribed by specific criteria, standards, and codes."[428]

At Seabrook, safety-related structures other than the containment are designed and constructed to comply with the 1971 edition of American Concrete Institute Standard 318, Building Code Requirements for Reinforced Concrete (ACI 318-71).[429] The containment structure is designed and constructed to comply with the 1975 edition of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Division 2, Subsection CC.[430] Generally speaking, ASR was not a known issue in concrete until the early 1980s.[431] "ACI 318-71 and the ASME Code do not include provisions for the analysis of structures affected by ASR."[432]

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[425] Ex. NER018, MPR-3727 at 1.2.2.

[426] Ex. INT010, Original LAR at PDF 9, 64–65.

[427] Id.

[428] Ex. NER004, SGH Testimony at 16.

[429] Ex. INT010, Original LAR at PDF 13; see Ex. NRC049, ACI 318-71 (non-public).

[430] Ex. INT010, Original LAR at PDF 14; see Ex. NRC050, ASME Code (non-public).

[431] Ex. NER019, Bayrak, O., "Structural Implications of ASR; State of the Art" (Feb. 2,2012) (FP100697) at 19 ("Earnest efforts to establish the implications of ASR with respect to the various limit states of concrete structures (axial, flexural, shear, and anchorage strength among others) did not begin until the early 1980's.") [hereinafter Ex. NER019, Bayrak White Paper] (non-public).

[432] Ex. INT010, Original LAR at PDF 7; see also id. at PDF 11 ("These codes do not include methods to address the effects of ASR on the structural properties used in the design of

Therefore, NextEra devised its own methodology to evaluate the effects of ASR on the structural properties of seismic Category I structures at Seabrook. "To support a long-term assessment of the impact of ASR on plant structures and provide a more realistic technical basis for a monitoring program, [MPR—a consultant to NextEra] included a recommendation to perform large-scale testing to obtain more representative data than were available in public literature."[433] The LSTP is the basis for a large part of NextEra's methodology.[434] The LSTP involved testing large concrete specimens constructed to reflect the structural characteristics of ASR-affected structures at Seabrook.[435] NextEra concluded that the LSTP was the best means by which to evaluate the impact of ASR on structural performance, instead of testing cores taken directly from Seabrook structures.[436] The FSEL performed the tests on the constructed specimens.[437]

FSEL conducted tests on the concrete specimens to reflect various levels of ASR cracking and to assess the impact on selected limit states.[438] These tests included "all relevant limit states except compression (i.e., flexure and reinforcement anchorage, shear, and anchor bolts and structural attachments to concrete)."[439] NextEra determined that "[t]he results of the test program demonstrated that none of the assessed limit states are reduced by ASR when

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concrete structures . . . . The analyses and testing to assess ASR material effects established a method to incorporate ASR into the Seabrook design basis that is not described in either ACI 318-71 or the ASME Code."); Ex. INT022, SEM at PDF 12 ("Neither ACI 318-71 nor the ASME code include provisions for the analysis and evaluation of structures affected by ASR."); Tr. at 946 (Buford).

[433] Ex. NER001, MPR Testimony at 55.

[434] Ex. INT010, Original LAR at PDF 15.

[435] Id.

[436] See Ex. NRC001-R, Staff Testimony at 24.

[437] Id.

[438] Ex. INT010, Original LAR at PDF 15; see supra note 38.

[439] Ex. INT010, Original LAR at PDF 16.

ASR expansion levels in plant structures are below those evaluated in the [LSTP]."[440] As long as ASR expansion levels are below those limits, NextEra concluded Seabrook structures "will have strength close to or in excess of that envisaged in the original design or as required by the code,"[441] despite the effect of ASR on the material properties of Seabrook concrete.

NextEra used LSTP test data to support other conclusions in the LAR. One of these was the effectiveness of the use of CCI to monitor the effects of ASR on the surface of Seabrook structures. The purpose of the ASR Expansion Monitoring Program is to gather crack width and extensometer measurements for monitoring against specified acceptance criteria (i.e., the ASR expansion limits) based on the LSTP to ensure ASR-related expansion at Seabrook does not exceed levels observed in the LSTP.[442] According to the LAR:

> One of the objectives of the test program was to identify effective methods for monitoring ASR. The program concluded that monitoring the in-plane and through-thickness expansion is effective for characterizing the significance of ASR in structures. A [CCI] methodology based on crack width summation was shown to be effective for in-plane expansion monitoring. Snap ring borehole extensometers . . . provided accurate and reliable measurements for monitoring through-thickness expansion.[443]

"The CCI estimates expansion on a concrete surface using measurements of crack widths along a pre-determined length or grid."[444] The CCI is the weighted average of the CI in the two measured in-plane directions (horizontal and vertical) at the concrete surface.[445] CI and CCI are similar yet distinct terms. CI is "[a] crack width summation technique for quantitatively

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[440] Id.

[441] Id. at PDF 15.

[442] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 3-1.3, 3-1.7 to -1.8 (non-public).

[443] Ex. INT010, Original LAR at PDF 17; see also Tr. at 326–27 (Bayrak) (confirming that the CCI methodology was validated in the LSTP).

[444] Ex. NER022-R, MPR-4262, "Shear and Reinforcement Anchorage Testing of Concrete Affected by Alkali-Silica Reaction," Vol. I, Rev. 1 (July 2016) & Vol. II, Rev. 0 (Jan. 2016) (FP100994) at 5-2 [hereinafter Ex. NER022-R, MPR-4262] (non-public).

[445] Ex. NER004, SGH Testimony at 34.

estimating tensile strains experienced by a reinforced concrete element. The [CI] is the ratio of the sum of crack widths to the length of which the crack summation activity is performed (i.e., the [gauge] length.)."[446] CCI is "[a] term used at Seabrook Station for a combination of [CI] values in both the horizontal and vertical directions."[447]

For the LSTP specimens, although the rate of expansion was approximately the same in all three directions until expansion reached [redacted] to [redacted] millimeters per meter (mm/m) (i.e., [redacted]% to [redacted]%), the specimens subsequently exhibited much greater expansion in the through-thickness direction than the in-plane directions.[448] These observations led MPR to conclude that using the CCI to monitor in-plane expansion sufficiently characterizes ASR development until at least 1.0 mm/m (0.1%) expansion, after which through-thickness monitoring by extensometers is required to monitor further ASR expansion.[449] NextEra relied on the results of the LSTP to support the installation of extensometers at an in-plane expansion of 1.0 mm/m (0.1%).[450]

Under the LAR, locations with no symptoms of ASR (Tier 1 areas) are generally inspected every five or ten years based on the existing SMP requirements.[451] Inspectors monitor locations with ASR symptoms that have CCI values below 1.0 mm/m (0.1%) in-plane expansion (Tier 2 areas) every two and a half years.[452] Locations with CCI values of 1.0 mm/m

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[446] Ex. NER002, MPR Testimony – Attachment 1 – Glossary at 2 [hereinafter Ex. NER002, MPR Glossary].

[447] Id. at 1.

[448] Ex. NER001, MPR Testimony at 91.

[449] Ex. INT019, MPR-4273 at B-4; Ex. INT021, MPR-4273 at B-4 (non-public).

[450] Ex. NER001, MPR Testimony at 122.

[451] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 2-1.7 to -1.8 (non-public); Ex. NER001, MPR Testimony at 126.

[452] Ex. INT010, Original LAR at PDF 33 tbl.5.

(0.1%) or greater (Tier 3 areas) are monitored for in-plane expansion, through-thickness expansion, and volumetric expansion every six months.[453]

Acceptance criteria for expansion levels directly incorporate LSTP conclusions.[454] LAR Table 4 and UFSAR Table 3.8-18 provide the ASR expansion limits (i.e., acceptance criteria) intended to ensure that expansion remains within the parameters validated by the LSTP results for Seabrook structures, i.e., that ASR does not reduce the assessed limit states.[455] Table 4 includes through-thickness expansion limits for shear, flexure, and reinforcement anchorage, as well as in-plane expansion limits for anchorage.[456] A CCI measurement of 1.0 mm/m (0.1%) or greater expansion provides the threshold for the installation of extensometers to determine compliance with the LAR Table 4/UFSAR Table 3.8-18 expansion limits.[457]

NextEra justified the use of extensometers to monitor expansion in the Tier 3 areas based on the LSTP. As the LAR explains:

> NextEra is installing extensometers for measuring through-thickness expansion of plant structures. The extensometer is installed in a borehole that is perpendicular to the face of the wall (or slab). The instrument consists of two anchors and a rod. The rod is attached to the anchor installed deep in the borehole and slides through a hole in the anchor installed near the surface. Expansion is monitored by measuring the distance between the end of rod and the reference surface on the anchor near the surface. The extensometer being installed is a snap-ring borehole extensometer. It was selected because it was shown to be accurate and reliable in the [LSTP].[458]

The LSTP results were also used by MPR to evaluate the impact of ASR on the material properties of Seabrook concrete and to determine whether changes to those properties reduce

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[453] Id.

[454] Ex. NER001, MPR Testimony at 112.

[455] Ex. INT010, Original LAR at PDF 17, 32 tbl.4.

[456] Id. at PDF 32 tbl.4.

[457] Id. at PDF 32 tbl.4, 74 tbl.3.8-18.

[458] Id. at PDF 31.

the capacity of Seabrook structures.[459] The material properties of concrete include compressive strength, tensile strength, and elastic modulus.[460] Staff witnesses stated that "[t]he compressive strength of a material, including concrete, is its capacity to withstand loads or stresses that tend to compress and reduce its size, as opposed to tensile strength, which is its capacity to withstand loads or stresses that tend to elongate and crack or split the material."[461] Further, "[t]he elastic modulus is the ratio of stress (force per unit area) to strain (ratio of change in length to the original length) in the elastic range of material behavior."[462] In addition, "[t]he elastic range of a material is the range in which the material can be loaded and unloaded without permanent deformation (i.e., an elastic structure deforms when a load is applied and, when the load is removed, it returns to its original state)."[463] The Staff defined shear strength as "the ability of a material to resist shear stress, . . . created when two planes of the same object attempt to slide past one another."[464] On the other hand, [f]lexural strength (or bending strength) is the ability of a structural member to resist a flexural load (moment), or the member's ability to resist bending when loaded."[465]

NextEra described the details of reinforced concrete, stating:

> Reinforced concrete is fabricated by placing wet (i.e., fresh) concrete into forms that contain mats of reinforcing bars . . . . The concrete mixture is then allowed to cure, such that it is bonded to the steel bars. In general, plain concrete (unreinforced) is relatively strong in compression (i.e., loads that push the

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[459] Ex. INT014, MPR-4288, Rev. 0, "Seabrook Station: Impact of Alkali-Silica Reaction on Structural Design Evaluations (July 2016) (Enclosure 2 to Letter SBK-L-16071) at 9, 11 [hereinafter Ex. INT014, MPR-4288] (non-public); Ex. INT012, MPR-4288, Rev. 0, "Seabrook Station: Impact of Alkali-Silica Reaction on Structural Design Evaluations (July 2016) (Enclosure 2 to Letter SBK-L-16071) at 9, 11 [hereinafter Ex. INT012, MPR-4288].

[460] Ex. NER001, MPR Testimony at 39.

[461] Ex. NRC001-R, Staff Testimony at 7.

[462] Id.

[463] Id.

[464] Id.

[465] Id.

> concrete together) and relatively weak in tension (i.e., loads that pull the concrete apart). The purpose of using reinforcing bars is to provide tensile capacity. In effect, tensile strength of concrete is not relied upon for many aspects of structural design, because tensile strength of typical concrete mixtures is roughly a tenth of the compressive strength of those mixtures. Reinforced concrete can be viewed as a composite, custom-made, structural material where concrete is used for its superior capacity in compression, and reinforcing steel is used to provide tensile strength, where needed.[466]

Among other things, MPR evaluated the material properties of cores obtained from the LSTP specimens before testing, which "indicated reductions in compressive strength, elastic modulus, and splitting tensile strength with increasing ASR-related expansion."[467] When a core is removed from one of the test specimens, however, the confining effect of the steel reinforcement is lost.[468] MPR relied upon the testing of the reinforced concrete specimens to conclude that evaluations of Seabrook structures should be based on the original material properties of the concrete rather than the degraded material properties identified in the core evaluations. MPR stated:

> Design Concrete Material Properties – Published literature identified that ASR reduces unconfined material properties of concrete (compressive strength, elastic modulus, tensile strength), which is consistent with the results obtained in the [LSTP]. However, the [LSTP] results also showed that the reduction in concrete material properties does not harm the structural performance of ASR-affected structures when through-thickness expansion is less than [mm/m or] %. These results confirm that structural performance of reinforced concrete structures cannot be reasonably re-evaluated for ASR simply by adjusting the ASR-affected properties of unconfined concrete and neglecting the self-equilibrating state of stress due to ASR-induced prestress. Based on this observation, structural evaluations of ASR-affected structures at Seabrook Station should conservatively use the material properties specified in the original design specifications.[469]

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[466] Ex. NER001, MPR Testimony at 34.

[467] Ex. NER022-R, MPR-4262 at 8–12 (non-public).

[468] Ex. INT012, MPR-4288 at 6-9.

[469] Id. at 2-3; Ex. INT014, MPR-4288 at 2-3 (non-public); see also Ex. INT019, MPR-4273 at 5-7 ("Because the [LSTP] specimens were much more representative of Seabrook Station than published literature . . . and the [LSTP] results were highly repeatable, structural evaluations for Seabrook Station can use the [LSTP] conclusion (i.e., no loss of capacity) in lieu of the results from published literature.").

Similarly, MPR relied upon the LSTP results to justify the use of the equations from ACI 318-71 and the 1975 ASME Code in its structural evaluations.[470] The capacity of Seabrook structures to withstand the loads (i.e., the demand) on those structures, including the additional load created by ASR, was determined using the code equations, which had been justified by the LSTP.[471]

Finally, NextEra relied on a correlation developed in the LSTP to determine the total through-thickness expansion in the Tier 3 locations, the locations with CCI values of 1.0 mm/m (0.1%) or greater.[472] Installation of extensometers provides a means for monitoring expansion from the time that the instrument is installed.[473] For structural evaluations at Seabrook, however, NextEra must be able to determine the total expansion that has occurred in a location affected by ASR from the original construction, which includes both the expansion measured by the extensometer and the expansion before the extensometer installation.[474] NextEra combined the expansion at such locations measured by the extensometers with "the expansion that occurred up to the time of instrument installation to yield the total through-thickness expansion to a given time."[475]

To determine the expansion before instrument installation, NextEra tested cores removed from the boreholes that housed the extensometers to measure the current elastic

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[470] Tr. at 582 (Bell) ("The validity of the code equations were amply demonstrated by the very extensive testing of the [LSTP].").

[471] Tr. at 965 (Bell) ("The finite element analysis does the demand side. It determines the internal forces. The capacity is determined by the code equations, justified by the [LSTP]."); Tr. at 965 (Bolourchi) ("[W]e are saying ASR expansion, it increases the load, the total demand, but it does not decrease the capacity. Therefore, the capacity [calculated using code equations] is verified by [the LSTP].").

[472] Ex. INT010, Original LAR at PDF 33 tbl.5.

[473] Ex. NER001, MPR Testimony at 18, 117.

[474] Ex. INT018-R, MPR-4153, Rev. 3 at iv; Ex. INT020, MPR-4153, Rev. 3 at iv (non-public).

[475] Ex. INT010, Original LAR at PDF 31.

modulus of those core samples.[476] It then used "an empirical correlation developed in the [LSTP] to correlate concrete elastic modulus measurements with the through-thickness expansion to date."[477] According to NextEra, combining past expansion with the future expansion detected by the extensometers provides a total measure of through-thickness expansion in areas affected by ASR.[478] The accuracy of the correlation is essential to verifying regulatory compliance because total through-thickness expansion is one of the measurements that ensures expansion remains within limits validated by the LSTP results for Seabrook structures.[479]

Thus, the LSTP played a critical role in determining the acceptable limits of ASR expansion for Seabrook structures, the monitoring of those structures to ensure that the limits are not exceeded, and the equations used to calculate the structures' capacity to withstand the loads placed upon them. The expansion limits and monitoring program, which were based on the results of the LSTP, will be used to determine the regulatory compliance of Seabrook structures through the end of the extended license—that is, for the next thirty years.[480]

Because the LSTP evaluated the effects of ASR on test specimens, not actual Seabrook concrete, the LSTP data is reliable and may be used to support the critical safety-related determinations described above only if the test specimens are representative of Seabrook

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[476] Ex. INT018-R, MPR-4153, Rev. 3 at 4-1; Ex. INT020, MPR-4153, Rev. 3 at 4-1 (non-public).

[477] Ex. INT010, Original LAR at PDF 31; see also Ex. INT018-R, MPR-4153, Rev. 3 at iv ("The correlation relates reduction in elastic modulus with measured expansion from beam specimens used during the large-scale ASR structural testing programs and provides a conservative estimate of pre-instrument expansion levels at Seabrook Station."); Tr. at 1001 (Carley) ("The modulus correlation was developed using only data from the [LSTP].").

[478] See Ex. INT010, Original LAR at PDF 31–32.

[479] Id. at PDF 17, 32 tbl.4

[480] See supra Part IV.D.

seismic Category I structures. Application of the LSTP results requires that the test specimens be representative of reinforced concrete at Seabrook.[481]

We accept NextEra's definition of representativeness as "[t]he ability to apply conclusions from one application to inform circumstances in another application. In the context of the reformulated contention, 'representativeness' refers to the results from the LSTP and their applicability to reinforced concrete structures at Seabrook Station."[482]

To design the test specimens for the LSTP, MPR selected a reference location at Seabrook. The chosen location was a horizontal section of the west wall of the B Electrical Tunnel.[483] That tunnel was the first location where ASR was identified at Seabrook.[484] NextEra concluded it was reasonable to use the B Electrical Tunnel as the reference location because the levels of ASR cracking there are "similar to other areas," the thickness of the walls (2 feet) is consistent with "most other areas," and the reinforcement configuration is "typical of most other structures."[485]

According to MPR, the final design of the test specimens must:

- [B]e representative of the reference location so that the test results can be used to calculate its structural capacity for the given failure modes,
- [U]se materials that are representative of the material of construction of the reference location,

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[481] See Ex. NER001, MPR Testimony at 20 ("For th[e LSTP] approach to be successful, the basis for the knowledge must be sufficiently representative of the object in question to be applicable."); Ex. INT019, MPR-4273 at 5-7 ("Because the [LSTP] specimens were much more representative of Seabrook Station than published literature . . . and the [LSTP] results were highly repeatable, structural evaluations for Seabrook Station can use the [LSTP] conclusion (i.e., no loss of capacity) in lieu of the results from published literature.").

[482] Ex. NER002, MPR Glossary at 3.

[483] Ex. NER001, MPR Testimony at 76–77.

[484] Id.

[485] Ex. NER026, MPR-3757, Rev. 4 "Shear and Reinforcement Anchorage Test Specimen Technical Evaluation" (May 2014) at 12 [hereinafter Ex. NER026, MPR-3757] (non-public).

- [B]e sufficiently representative to the other structures at Seabrook Station such that the test results can be applied to those structures using adjustments derived from extensive published data,
- [E]nsure failure in the desired failure mode (out-of-plane shear and reinforcement anchorage, respectively), and
- [A]llow for the rapid development of ASR.[486]

2. Concrete

C-10 argued the composition of the LSTP concrete was not representative of Seabrook concrete.[487] Concrete is comprised of "(1) coarse and fine aggregates, (gravel and sand, respectively) that provide strength; (2) cement, which functions as a glue that holds the aggregates together; and (3) water for cement hydration, which is the set of chemical reactions that transforms the cement from a dry powder to the 'glue' that bonds the concrete constituents together."[488]

Dr. Saouma testified that NextEra used a different aggregate in the LSTP specimens than that used in Seabrook concrete.[489] In particular, NextEra used a blend of highly reactive coarse aggregate and slow reacting coarse aggregate along with sand as opposed to the coarse aggregate present at Seabrook.[490] Dr. Saouma stated that the LSTP aggregate mixture does not have the same reactivity as Seabrook aggregate.[491] He further testified that "the cracking pattern that you have as the result of sand being the driving force as opposed to the

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[486] Id. at 16 (non-public).

[487] C-10 Initial SOP at 10.

[488] Ex. NER001, MPR Testimony at 34; see also Ex. INT031, Dr. Saouma Review of Selected Documents at 3 ("Concrete is a delicate dosage of cement, aggregates (about 3/4" max), sand and water designed to meet specific criteria.").

[489] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony (non-public) at 10–11; Ex. INT027, Dr. Saouma Pre-Filed Testimony at 10–11; Tr. at 632 (Saouma).

[490] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony (non-public) at 10–11; Ex. INT027, Dr. Saouma Pre-Filed Testimony at 10–11; Tr. at 604, 1001–02 (Saouma).

[491] Tr. at 632–33 (Saouma).

aggregate is quite different."[492] In his opinion, the cracking pattern observed in the LSTP specimens is not representative of what would happen at Seabrook.[493]

a. Motion in Limine

At the outset, we must address NextEra's claim that testimony concerning concrete mineralogy is beyond the scope of the reformulated contention.[494] We find that both the physical and chemical properties of concrete (i.e., its mineralogy) are "fairly encompassed by the description of [the admissible contentions] that [C-10] set forth in its petition for hearing."[495] The Motion in Limine is denied in this respect.

An evidentiary hearing convened in response to an intervenor challenge to a proposed agency licensing action is limited to any admitted contentions. The "reach of a contention necessarily hinges upon its terms coupled with its stated bases."[496] Intervenors are not required to prove their case at the contention stage, nor are they required to "provide an exhaustive list of possible bases" at that time.[497] But an intervenor "'may not freely change the focus of an admitted contention at will' to add a host of new issues and objections that could have been

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[492] Tr. at 604 (Saouma).

[493] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 11 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11.

[494] NextEra MIL 2 at 16, 17.

[495] Entergy Nuclear Generation Co. & Entergy Nuclear Operations, Inc. (Pilgrim Nuclear Power Station), CLI-10-11, 71 NRC 287, 310 (2010).

[496] Pilgrim, CLI-10-11, 71 NRC at 309 (citing Pub. Serv. Co. of N.H. (Seabrook Station, Units 1 & 2), ALAB-899, 28 NRC 93, 97 (1988), aff'd sub nom. Mass. v. NRC, 924 F.2d 311 (D.C. Cir.), cert. denied, 502 U.S. 899 (1991); Duke Energy Corp. (McGuire Nuclear Station, Units 1 & 2; Catawba Nuclear Station, Units 1 & 2), CLI-02-28, 56 NRC 373, 379, 383 (2002)).

[497] La. Energy Servs., LP (Nat'l Enrichment Facility), CLI-04-35, 60 NRC 619, 623 (2004); see also Calvert Cliffs Nuclear Project, LLC, and Unistar Nuclear Operating Servs., LLC (Calvert Cliffs Nuclear Power Plant, Unit 3), LBP-12-17, 76 NRC 71, 85 (2012) ("[A]s long as the facts relied on by [the Intervenor] fall within the 'envelope' of the contention, they are properly before the Board. A petitioner is not required to set forth all of its evidence or to prove its contentions at the admissibility stage."); Nuclear Innovation N. Am. LLC (S. Tex. Project, Units 3 & 4), LBP-11-25, 74 NRC 380, 397 (2011) ("At the contention admissibility stage of a proceeding, Intervenors need not marshal their evidence as though preparing for an evidentiary hearing.").

raised at the outset."[498] When an intervenor's testimony or exhibits are alleged to fall outside the scope of an admitted contention, licensing boards must decide whether the proffered evidence is within the "reasonably inferred bounds" of the admitted contention.[499] Information offered in evidence, "even if not specifically stated in the original contention and bases[, may] be relevant if it falls within the 'envelope,' 'reach,' or 'focus' of the contention when read with the original bases offered for it."[500]

Contentions A, B, C, D, and H provided the bases of the reformulated contention, and we will therefore look to those contentions and the facts C-10 alleged in support to determine whether specific issues fall within the scope of the reformulated contention.[501]

The reformulated contention alleges that the LSTP data fails to represent the progression of ASR at Seabrook adequately and therefore fails to provide an adequate basis for establishing monitoring, inspection criteria, and inspection intervals.[502] On its face, the reformulated contention is broad enough to cover any failure of the LSTP data to adequately represent the effect of ASR on Seabrook structures, provided that such failure is related to establishing monitoring, inspection criteria, or inspection intervals.

Contention D, one of the bases of the reformulated contention, alleged that the LSTP data fails to represent the progression of ASR at Seabrook adequately.[503] As the Commission noted, "[i]n Contention D, C-10 challenges the overall representative nature of the data from the

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[498] Licensing Board Order (Ruling on NextEra's Motion in Limine) (June 7, 2019) at 7 (unpublished) (quoting McGuire, CLI-02-28, 56 NRC at 386).

[499] Pilgrim, CLI-10-11, 71 NRC at 309.

[500] Duke Energy Corp. (Catawba Nuclear Station, Units 1 & 2), LBP-04-12, 59 NRC 388, 391 (2004).

[501] See supra Part II.B.

[502] LBP-17-7, 86 NRC at 90.

[503] C-10 Petition at 2, 8–11.

[LSTP]."[504] Quoting the LAR, Contention D emphasized that "[a]pplication of the results of the [LSTP] requires that the test specimens be representative of reinforced concrete at Seabrook Station and that expansion behavior of concrete at the plant be similar to that observed in the test specimens."[505] Like the reformulated contention, Contention D implies that the allegedly inadequate test data fails to provide a sufficient basis for establishing any monitoring program or methodology. Therefore, it supports C-10's argument that its contentions "express concern about the lack of representativeness of [LSTP] results for purposes of establishing monitoring, inspection criteria, and inspection intervals."[506]

The Board also admitted Contention A, which directly challenged NextEra's monitoring program, including its reliance on crack indexing.[507] As the Board explained, "[b]ecause NextEra will use 'an empirical correlation developed in the [LSTP]' to correlate the concrete elastic modulus measurements it obtains from core sample testing with the through-thickness expansion to date, the validity of NextEra's calculations depends on whether the [LSTP] specimens were representative of Seabrook concrete." [508] The Board also observed that the LAR "justifies a monitoring program based on the CCI and snap ring borehole extensometers because those methodologies were found accurate and reliable in the test program. NextEra justifies its crack width methodology on that basis."[509] The Board further noted that Contention D "maintains that the test programs' data are not representative of the progression of ASR at

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[504] CLI-18-4, 87 NRC at 94.

[505] C-10 Petition at 9 (quoting Ex. INT019, MPR-4273 at 6-3).

[506] [C-10]'s Opposition to NextEra's Motion in Limine at 6 (May 3, 2019) [hereinafter C-10 Opp. to NextEra MIL 1].

[507] CLI-18-4, 87 NRC at 100–02; LBP-17-7, 86 NRC at 92–102.

[508] LBP-17-7, 86 NRC at 100 (citations omitted).

[509] Id. (citation omitted).

Seabrook."[510] Thus, "the Board's ruling on Contention D necessarily implicates the question whether NextEra's monitoring program will provide an adequate means of assuring that ASR progression at Seabrook remains within acceptable levels."[511]

Because the representativeness of the LSTP concrete is at the crux of Contention D, the mineralogy of the concrete, defined as its chemical[512] and physical properties,[513] is logically enveloped within the basis of that contention and the reformulated contention.[514] Although NextEra argued that it measured representativeness based solely on structural characteristics,[515] we see no such limitation in the scope of Contention D, the other admitted contentions, or the reformulated contention.[516] We admitted testimony and exhibits indicating

[510] Id. at 100–01.

[511] Id. at 101.

[512] Chemical properties refer to the chemical composition and crystalline structure. See Ex. NER077, NextEra Response to Ex. INT051-R at 4. The chemical properties of particular concern to Dr. Saouma are the reactivity of the aggregate and resulting type of gel. See Ex. INT051-R, Dr. Saouma Supp. Testimony at 2.

[513] The physical properties include shape, hardness, strength, and size distribution of aggregate components. See Ex. NER077, NextEra Response to Ex. INT051-R at 4.

[514] We discuss the merits of the argument, below, in Part VIII.A.2.d. C-10 argued that the type of aggregate is important in determining representativeness in its original Petition. C-10 Petition at 9 ("NextEra must also systematically evaluate the concrete via petrography and physical testing of cores, and evaluate the expansive capacity of ASR based on ASTM standard tests as promulgated by ASTM Committee C-9 on Concrete and Aggregates[.]").

[515] NextEra's Proposed Findings of Fact and Conclusions of Law at 54–55; Ex. NER001, MPR Testimony at 21 ("[T]he FSEL testing were structurally representative of concrete used in constructing Seabrook structures."); id. at 135–36; see also Ex. INT019, MPR-4273 at 2-6 to -7; Ex. NER077, NextEra Response to Ex. INT051-R at 5–7; Ex. NRC091, Staff Response to Ex. INT051-R at 3 (listing several characteristics NextEra used to determine representativeness).

[516] See LBP-17-7, 86 NRC at 113–14 (quoting Ex. INT019, MPR-4273 at 6-3); C-10 Petition at 11 ("[T]he [LSTP] data cannot, in any meaningful way, 'stand in' for or 'represent' the current state of in-situ concrete at the Seabrook reactor[.]").

that the mineralogy affects the rate of ASR expansion,[517] the timing of ASR reactions,[518] the type of ASR gel,[519] the pattern of ASR cracking,[520] and the use of CCI.[521] Indeed, NextEra acknowledged that the aggregate size impacts structural capacity,[522] and that particular chemical characteristics of ASR may affect the expansion rate and cracking pattern.[523] Further, the connection between mineralogy and the use of CCI supports our finding that mineralogy is within the scope.[524] Our holding aligns with Commission precedent because the reformulated contention is not being "changed" or impermissibly stretched.[525] Rather, C-10 is supporting its existing arguments regarding the lack of concrete representativeness and its implications for NextEra's reliance on CCI and elastic modulus correlation to monitor expansion.

Nevertheless, NextEra claimed that the reformulated contention is limited to a narrow list of differences between the LSTP specimens and the Seabrook structures: "age; length of time

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[517] Ex. NER012, The Institution of Structural Engineers, "Structural Effects of Alkali-Silica Reaction" (July 1992) at 10 [hereinafter Ex. NER012, ISE Structural Effects of [ASR]] (non-public); see Ex. NRC091, Staff Response to Ex. INT051-R at 5.

[518] Ex. INT035, T. Katayama, "An Attempt to Estimate Past Expansion of Concrete Based on Petrographic Stage of Alkali-Silica Reaction," Proc. 39th International Conference on Cement Microscopy, Canada, pp. 217–236 (2017) [hereinafter Ex. INT035, T. Katayama] (non-public).

[519] Tr. at 981–82 (Saouma); Ex. NER012, ISE Structural Effects of [ASR] at 11 (non-public).

[520] Tr. at 981–82, 1001–02, 1082–83 (Saouma); Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 11 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11; see Ex. INT040, P. Rivard and G. Ballivy, "Assessment of the expansion related to alkali-silica reaction by the Damage Rating Index Method," 19 Construction and Building Materials 83 (2005) at 89 [hereinafter Ex. INT040, Assessment of ASR Using DRI] (non-public).

[521] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 11 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11

[522] Ex. NER077, NextEra Response to Ex. INT051-R at 3 ("The size of aggregate and the surface roughness (i.e., angular surfaces from crushing the rocks rather than smooth surfaces) can both affect the aggregate interlock mechanism for developing shear strength (i.e., capacity).").

[523] Id. at 4–6.

[524] LBP-17-7, 86 NRC at 95–96.

[525] McGuire, CLI-02-28, 56 NRC at 386.

ASR has propagated; exposure to fresh water at various levels; exposure to salt in the water at different levels and concentrations; the effects of heat; and the effects of radiation."[526] While we agree the preceding factors are some of the bases of Contention D, it is not an exhaustive list. The sentence in the C-10 Petition from which this list is derived ends with the word "etc.," confirming that it was not intended to be a complete list of C-10's concerns, but rather a list of examples.[527] In addition, as further elaborated below, each of these bases is a topic encompassed within the "envelope" of concrete mineralogy.

In our ruling on contention admissibility, we found that C-10 had provided sufficient factual support for those listed bases to demonstrate a genuine dispute with the LAR.[528] There, we "concluded that Contention D was admissible as to the question of representativeness of the test program."[529] We expressly declined to incorporate the list of bases cited in the Petition into the text of the reformulated contention.[530] Rather, we admitted a contention, not its bases.[531] Therefore, contrary to NextEra's argument, we did not identify an "exhaustive list of possible bases."[532] As noted, information offered in evidence, "even if not specifically stated in the

[526] NextEra MIL 2 at 15 (citing CLI-18-4, 87 NRC at 104).

[527] C-10 Petition at 11 ("Furthermore, the concrete walls of Seabrook, sitting in a salt marsh on the New Hampshire coast, present far too many variables to allow even a well-performed set of tests (as the [LSTP] tests obviously were) in Texas to reflect their characteristics: their age; the length of time ASR has propagated; the effect of the fresh water at varying levels; the effect of the salt in the water at varying levels of height and concentration; the effects of heat; the effects of radiation on certain vital structures; etc.").

[528] LBP-17-7, 86 NRC at 113.

[529] CLI-18-4, 87 NRC at 104.

[530] LBP-17-7, 86 NRC at 127.

[531] 10 C.F.R. § 2.309(a); see Tenn. Valley Auth. (Watts Bar Nuclear Plant, Unit 2), LBP-09-26, 70 NRC 939, 988 (2009).

[532] La. Energy Servs., CLI-04-35, 60 NRC at 623.

original contention and bases[, may] be relevant if it falls within the 'envelope,' 'reach,' or 'focus' of the contention when read with the original bases offered for it."[533]

Furthermore, although we reject NextEra's overly narrow list of exclusive bases of the reformulated contention, concrete mineralogy actually permeates each of those bases. For instance, the mineralogy of the aggregate affects the length of time ASR has propagated, which NextEra acknowledged as one of the originally stated bases of the reformulated contention.[534] One of the main reasons Seabrook concrete is susceptible to ASR and initially escaped detection is due to slowly reactive aggregate, which was not captured by a flawed American Society of Testing and Materials (ASTM) reactivity test.[535] Therefore, the mineralogy of Seabrook concrete, which is slowly reactive, resulted in ASR occurring later on in the plant, affecting the overall length of time ASR has propagated at Seabrook.[536]

C-10 raised concerns regarding the effect of radiation on the reactivity of Seabrook concrete.[537] At its core, the reactivity of ASR depends on concrete mineralogy.[538] As acknowledged by all parties, aggregate coarseness has a substantial impact on the rate of ASR expansion.[539] In its Petition, C-10 stated that radiation "can potentially accelerate ASR activity

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[533] Catawba, LBP-04-12, 59 NRC at 391.

[534] NextEra MIL 2 at 15 (citing CLI-18-4, 87 NRC at 104).

[535] Tr. at 402 (Bayrak); Ex. NRC001-R, Staff Testimony at 9–10.

[536] The "length of time ASR has propagated" and "age" of the concrete are both representativeness concerns regarding temporality; thus, this conclusion stretches to two original bases. See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5 ("The kinetics of the [ASR] reaction (that is the rate of expansion) is a function of time, temperature and concrete relative humidity.").

[537] C-10 Petition at 10.

[538] Ex. NER012, ISE Structural Effects of [ASR] at 10–11 (non-public).

[539] See Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 6, 11 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 6, 11; Ex. NER022-R, MPR-4262 at K-5 (non-public); Ex. NRC001-R, Staff Testimony at 9–10, 50–51, 62; Tr. at 633 (Simons).

or cause ASR to occur with aggregates that are not normally reactive."[540] Therefore, reactivity, which is encompassed within the broader concerns of mineralogy, was raised in the Petition and is within the scope of the reformulated contention.

Furthermore, the remaining bases cited in C-10's Petition generally relate to the effects of heat, water, and humidity on the reactivity of ASR, whose impacts vary depending on the mineralogy.[541] These three subjects permeate many of C-10's concerns about ASR at Seabrook. While the semantics of C-10's arguments have progressed, many of Dr. Saouma's arguments are rooted in these areas.[542] For example, Dr. Saouma (1) stated NextEra's use of CCI fails to capture internal relative humidity;[543] (2) emphasized humidity and time as key drivers of ASR;[544] (3) stated salt may corrode steel rebar if it travels through ASR cracks;[545] (4) noted ASR expansions depends on temperature, among other factors;[546] and (5) suggested water below ground increases the internal relative humidity.[547] These arguments stem from the Petition even though they are not stated in the same terms, relate to ASR reactivity, and fall under the reach of concerns regarding concrete mineralogy.

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[540] C-10 Petition at 10 (quoting RES, NUREG/CR-7171, A Review of the Effects of Radiation on Microstructure and Properties of Concretes Used in Nuclear Power Plants, at 88–89 (Nov. 2013) (ADAMS Accession No. ML13325B077)).

[541] The bases discussed in this paragraph are "the effect of the fresh water at varying levels; the effect of the salt in the water at varying levels of height and concentration; the effects of heat." C-10 Petition at 11.

[542] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 20 ("ASR proceeds more rapidly in hot and moist conditions." (quoting Ex. INT019, MPR-4273 at 4-8)).

[543] Ex. INT032, Dr. Saouma Rebuttal Testimony at 12 ("Relative humidity/temperature is a driver of the ASR reaction (if over 80%) or an impediment (if below 80%). This has an influence on CI readings . . . NextEra does not account for it in the field measurement of the CI or the subsequent finite element analysis."); id. at 21–24; Ex. INT028, Dr. Saouma Rebuttal Testimony at 21–24 (non-public).

[544] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5.

[545] Id. at 22; Ex. INT032, Dr. Saouma Rebuttal Testimony at 36.

[546] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5–6, 11–13, 21–22, 33.

[547] Id. at 21–22, 26, 33.

We also note that one component of mineralogy, the resulting type of ASR gel, was a topic initially raised by Dr. Paul Brown, the original expert cited in C-10's Petition. Specifically, Dr. Brown criticized NextEra for exhibiting a fundamental misunderstanding of ASR kinetics, stating NextEra failed to consider that the ratio of ASR gel in a structure affects the stress on the surrounding concrete.[548] Therefore, mineralogy, which determines the viscosity of ASR gel,[549] was an issue raised at the outset of this proceeding and is within the scope of the reformulated contention.

We therefore deny NextEra's Motion in Limine as it pertains to the physical and chemical properties of concrete.

b. C-10's Prima Facie Case

For the test specimens used in the LSTP, NextEra obtained half of the coarse aggregate from a quarry in Maine and the other half from a quarry in New Mexico.[550] NextEra intentionally chose highly reactive coarse aggregate from the quarry in New Mexico to accelerate ASR expansion.[551] To justify that choice, NextEra witnesses stated that chemical mineralogy is not critical to representativeness.[552] It argued that even if an exact replication of Seabrook's concrete were possible, ASR expansion would not occur in a reasonable time frame to gather

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[548] C-10 Petition at 5 (quoting P.W. Brown, Commentary on Seabrook Station License Amendment Request 16-03 at 3 (Sept. 30, 2016) (ADAMS Accession No. ML16306A248) ("ASR gel is not a compound of fixed composition. It has a variable monovalent cation-to-calcium ratio and a compositionally dependent viscosity. A high ratio produces a gel which is fluid and will accommodate to the pores and voids. As this ratio decreases the gel becomes sufficiently viscous that osmotic effects can place stress on the surrounding concrete. A local source of restraint can, for some period of time, minimize dimensional instability and cracking. However, restraint does not stop the progress of the reaction.")).

[549] Ex. NER012, ISE Structural Effects of [ASR] at 11 (non-public).

[550] Tr. at 633 (Simons).

[551] Id.

[552] Ex. NER001, MPR Testimony at 82–83; Tr. at 642 (Bayrak) ("[W]e're not aiming to model the chemical reaction. This was never an intent.").

probative data.[553] In accordance with industry practice, the concrete was doped with [redacted] to accelerate the expansion further.[554] By the time of the testing, the chemical composition of the LSTP concrete differed greatly from the concrete at Seabrook.[555] NextEra determined that Seabrook concrete components matched "as closely as reasonably achievable."[556]

In developing the test specimens, NextEra identified characteristics of concrete components deemed critical to structural capacity.[557] For example, NextEra recognized the size and roughness of coarse aggregate was a crucial component because both can affect the "aggregate interlock mechanism for developing shear strength," which, in turn, can affect a component's structural capacity.[558]

Dr. Saouma agreed that there is a "very strong similarity" in the gradation between the aggregates used in the test specimens and the gradation of the Seabrook aggregates.[559] But Dr. Saouma stated that it is also essential to have a mineralogic comparison of the aggregates.[560] As noted above, ASR is a chemical reaction that produces an alkali-silicate gel that expands as it absorbs moisture.[561] The expansion exerts stress on the surrounding concrete and results in cracking.[562] According to Dr. Saouma, "[d]ifferent kinds of reactive

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[553] NextEra's Proposed Findings of Fact and Conclusions of Law at 54.

[554] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11; Ex. NER022-R, MPR-4262 at 3-2, 4-7, 4-11 (non-public).

[555] Ex. NER022-R, MPR-4262 at 4-7, 4-11 (non-public).

[556] See Ex. NRC091, Staff Response to Ex. INT051-R at 3.

[557] Ex. NER077, NextEra Response to Ex. INT051-R at 3.

[558] Id.

[559] Tr. at 1074 (Saouma).

[560] Tr. at 1082–83 (Saouma); Ex. INT051-R, Dr. Saouma Supp. Testimony at 1–2.

[561] See supra note 423 and accompanying text.

[562] Ex. INT010, Original LAR at PDF 9.

aggregates or sand will cause different types of gel. The calcium content of the gel . . . is known to be critical in characterizing the ASR expansion."[563]

As C-10 acknowledged, Dr. Saouma did not claim that the chemical characteristics of aggregates and the associated ASR gel are relevant to structural capacity.[564] But C-10 relied on his testimony to support its claim that the comparative chemical characteristics of the aggregates and gels in Seabrook concrete and LSTP specimens are relevant to (1) NextEra's program for monitoring ASR development through crack indexing; and (2) its use of the correlation method to determine past expansion.[565]

Dr. Saouma testified that it is necessary to have a comparison of the mineralogy of the aggregate at Seabrook and the mineralogy of the aggregate used in the LSTP "because mineralogy plays an important role in the formation of ASR, in the formation of the gel, in the type of gel, in the nature of the expansion, [and] in the type of cracks that we expect."[566] Dr. Saouma testified that reactive sand was the driving force for ASR expansion in the LSTP, whereas at Seabrook, the driving force is the coarse aggregates; therefore, the cracking pattern is likely to be entirely different.[567] "[S]and will result in a rapid expansion, and aggregates will cause a slower, but larger, future expansion."[568] NextEra witness Dr. Bayrak confirmed the presence of highly reactive sand in the LSTP specimens.[569] In Dr. Saouma's opinion, because the chemical composition of the concrete in the LSTP specimens differed greatly from the concrete at Seabrook, "one could not use the cracking pattern or the expansion rates to be

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[563] Ex. INT031, Dr. Saouma Review of Selected Documents at 3.

[564] C-10's Redacted Supp. Proposed Findings of Fact and Conclusions of Law at 2.

[565] Id. at 3.

[566] Tr. at 1082–83 (Saouma).

[567] Tr. at 424–26, 604, 981–82, 1001–02 (Saouma).

[568] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 6.

[569] Tr. at 985 (Bayrak).

indicative of what would happen at Seabrook."[570] He testified that the differences between LSTP and Seabrook concrete will impact the ability to correlate "crack widths, expansions, combined crack indexing (CCIs), and crack patterns with Seabrook."[571]

Several reports in the record support Dr. Saouma's opinion. He cited the work of Poyet, et al., confirming that "fine aggregates (sand) will yield a faster reaction . . . than coarse ones. However, the coarse aggregates will ultimately yield larger expansion than the one caused by the sand."[572] Also, according to the Institution of Structural Engineers (ISE), the "type, particle size and proportion of silica in the aggregate will influence the rate and severity of the reactivity of the concrete."[573] The ISE document further explains that:

> The characteristics of the alkali-silica gel formed by the [ASR] reaction vary with its chemical composition, temperature, moisture content and pressure. Its consistency can range from that of heavy engine oil to that of polyethylene. Some aggregates, e.g. Danish flints, Beltane opal, generate sufficient quantities of gel for it to exude from cracks. Conversely, in most UK cases of ASR, gel is visible only when cores are petrographically examined.[574]

A study by Tetsuya Katayama concerning concrete expansion also supports Dr. Saouma's opinion that variations in mineralogy affect reaction vigor, reaction timing, and crack width.[575]

In addition, Dr. Saouma questioned the representativeness of the LSTP specimens because they "were essentially stored in a greenhouse," under very hot and very humid conditions that are not "conducive to the drying of the [concrete] surface."[576] By contrast, Seabrook has lower relative humidity, and "[o]n most of the surface dry shrinkage has occurred

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[570] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11.

[571] Id.

[572] Id. (citing Ex. INT034, Poyet et al. at 229 (non-public)).

[573] Ex. NER012, ISE Structural Effects of [ASR] at 10 (non-public).

[574] Id. at 11 (non-public).

[575] See Ex. INT035, T. Katayama.

[576] Tr. at 475–76 (Saouma).

and the first couple of inches have a lower relative humidity."[577] The rate of ASR expansion "is a function of time, temperature[,] and concrete relative humidity."[578] The conditions at Seabrook are quite different from the conditions at the LSTP site in Texas.[579] In New Hampshire, the temperature is much lower on the surface of a concrete wall, and there is a thermal gradient with much warmer concrete and greater relative humidity inside.[580] Thus, Dr. Saouma testified that conditions during the LSTP were much more conducive to the formation of ASR cracks at the concrete surface than are conditions at Seabrook.[581] Because of the lower relative humidity at the surface, Seabrook structures may show little or no surface cracking but may have significant interior cracking, where the relative humidity is at or above the 80% threshold necessary for ASR reactivity.[582]

The relative humidity gradient postulated by Dr. Saouma finds some support in a study of ASR in five dams in the southwestern United States.[583] The report, conducted jointly by a private company and the Department of the Interior's Bureau of Reclamation, found that in three of the dams, "[m]ost of the concrete . . . still appears to contain enough moisture to permit expansion from [ASR]."[584] Yet, "concrete within several inches of exposed surfaces [wa]s sufficiently dry to preclude expansion."[585]

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[577] Tr. at 476 (Saouma).

[578] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5.

[579] Id. at 20–21.

[580] Id.

[581] Tr. at 490–94 (Saouma).

[582] Id.; Ex. INT007, Dr. Saouma Review of Selected Documents at 8 (non-public); Ex. INT031, Dr. Saouma Review of Selected Documents at 9; Ex. INT028, Dr. Saouma Rebuttal Testimony at 21–25 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 21–25.

[583] See Ex. INT037, Stark, D., & De Puy, G. W. (1987). Alkali-silica reaction in five dams in southwestern United States. ACI Special Publication, 100, 1759-1786 (non-public).

[584] Id. at 1761 (non-public).

[585] Id. (non-public).

After the evidentiary hearing, NextEra produced the Santa Ana Aggregates document, as directed by the Board in the Order granting C-10's Motion to Compel.[586] In his supplemental written testimony concerning that document, Dr. Saouma stated that it "lack[ed] a direct mineralogical comparison (both physical and chemical) between the test aggregate (and sand) and the aggregate (and sand) used in [the] Seabrook structures."[587] He further explained that he has not "found such a mineralogical comparison in any of the other documents that NextEra has identified as having information about the petrographic characteristics of Seabrook and LSTP test specimen aggregates."[588] Moreover, Dr. Saouma stated that the document failed to specify "whether the Santa Ana aggregate was used in the LSTP, or whether it was merely sampled."[589] He concluded that "NextEra has not provided enough information to allow a comparison between the mineralogy of Seabrook concrete and LSTP test specimens, and consequentially the concrete is not proven to be sufficiently representative."[590]

Dr. Saouma's opinion, together with the reports he cited in support of his opinion, are sufficient to meet C-10's burden to establish a prima facie case that the LSTP concrete is not sufficiently representative of Seabrook concrete to support NextEra's CCI methodology. The burden of proof on that issue therefore shifts to NextEra.[591]

C-10 also argued that the lack of data on the comparative chemical characteristics of the aggregates and gels in Seabrook concrete and LSTP test specimens undermines the reliability of the elastic modulus correlation used to determine past expansion.[592] As explained above, to

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[586] See supra Part II.F.

[587] See Ex. INT051-R, Dr. Saouma Supp. Testimony at 1.

[588] Id. at 2.

[589] Id. at 1.

[590] Id. at 2.

[591] See supra Part III.B.1.

[592] C-10's Redacted Supp. Proposed Findings of Fact and Conclusions of Law at 3.

determine the ASR-induced expansion before extensometer installation, NextEra uses an empirical correlation developed in the LSTP to correlate elastic modulus measurements with the through-thickness expansion to the date of the installation.[593] The accuracy of that correlation is essential to determining total expansion and thus verifying regulatory compliance.[594] C-10 has not cited any testimony or other evidence, however, sufficient to make a prima facie case on this claim. Dr. Saouma did testify that differences in aggregate chemistry may affect crack width, cracking patterns, and expansion rates.[595] However, he did not provide any evidence that aggregate chemistry will change the correlation between reduced elastic modulus and past expansion. We therefore will not consider further the claim that the comparative chemical characteristics of the aggregates and gels in Seabrook concrete and LSTP test specimens undermine the reliability of the elastic modulus correlation.

c. NextEra and Staff Responses

NextEra expert witness Dr. Bayrak confirmed the use of different aggregate in the LSTP concrete.[596] NextEra argued, however, that the composition was similar to Seabrook.[597] The Staff agreed with NextEra and argued the LSTP is sufficiently representative even if the coarse aggregate is not identical.[598] The Staff reviewed each component of the LSTP, finding each to be representative and/or bounding of the concrete at Seabrook.[599] The Staff found that the test specimens "reflected the typical characteristics of ASR-affected structures at Seabrook[,]" such

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[593] See supra notes 476–479 and accompanying text.

[594] See infra Part VIII.D.

[595] Tr. at 981–82, 1001–02, 1082–83 (Saouma); Ex. INT032, Dr. Saouma Rebuttal Testimony at 12.

[596] Tr. at 985 (Bayrak).

[597] Tr. at 633–34 (Simons) (stating SGH sent the blend of aggregate to an expert petrographer who confirmed its similarity to the plant).

[598] NRC Staff SOP at 32–33.

[599] Id. at 33.

as utilizing a similar scale and structural context and similar reinforcement ratios and configurations.[600] The Staff also determined the concrete of the test specimens reasonably reflected the properties of the concrete in Seabrook structures.[601]

NextEra maintained that it provided sufficient information to permit an adequate mineralogical comparison of the LSTP aggregate and the Seabrook aggregate.[602] Several of the documents it cited, however, while apparently produced during the mandatory disclosure process, were not entered into evidence.[603] We may not base our ruling on documents that are not part of the evidentiary record.[604] But we need not determine whether NextEra produced sufficient information to permit a comparison of the chemical characteristics of the LSTP aggregate and the Seabrook aggregate, because NextEra witnesses acknowledged that "to achieve bounding levels of ASR expansion in a useful timeframe . . . the LSTP necessarily used a faster-reacting aggregate with similar physical characteristics (i.e., size and surface roughness), but with different chemical characteristics (composition, crystalline structure)."[605] Thus, it is undisputed that the Seabrook aggregate and the LSTP aggregate differed in their chemical composition and structure. The question we must resolve is whether those acknowledged differences are important in determining representativeness.

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[600] Id. at 34.

[601] Id. at 35 ("For example, the concrete mix design for the specimens was based on specifications used at Seabrook (e.g., compressive strength, coarse aggregate gradation and type, water-to-cement ratio, cement type, aggregate proportions) and, in part, included constituents obtained from sources similar to those used during the construction of the plant.").

[602] See NextEra Motion to Compel Letter at 2; Ex. NER077, NextEra Response to Ex. INT051-R at 7–8.

[603] NER077, NextEra Response to Ex. INT051-R at 8 n.29.

[604] See 10 C.F.R. § 2.713(c) ("An initial decision will . . . be based on the whole record and supported by reliable, probative, and substantial evidence.").

[605] Ex. NER077, NextEra Response to Ex. INT051-R at 4 (citations omitted).

NextEra witnesses stated that the acknowledged differences are not important.[606] They testified that "[t]he LSTP did not include any critical characteristics that pertain to the chemical characteristics of the minerals in the aggregate."[607] They agreed with Dr. Saouma on "several key facts . . . including the importance of the crystalline structure of the silica within the aggregate on reactivity, the importance of aggregate chemical characteristics on reaction rate, and the fact that expansion of gel causes cracking."[608] NextEra witnesses "also acknowledge[d] that differences in concrete mixture design may result in ASR gel with different chemical and physical attributes,"[609] and "that differences in concrete mixture design may affect the typical crack pattern."[610] But they emphasized that "NextEra's approach is focused on the structural implications of ASR across a wide range of expansion levels" and that "[t]hese structural implications are not significantly affected by the rate of reaction, characteristics of the gel, or the specific pattern of microcracks comprising a given expansion level."[611]

The Staff agreed with NextEra that the differences in concrete between Seabrook and the LSTP specimens are not significant for the purposes of determining representativeness.[612] The Staff's conclusion "that the Seabrook ASR expansion monitoring program is acceptable and provides reasonable assurance that Seabrook structures will continue to meet the NRC's requirements"[613] remained unchanged after NextEra produced the Santa Ana Aggregates Report.

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[606] Id.

[607] Id.

[608] Id. at 5 (citing Ex. NER001, MPR Testimony at 38–39, 45).

[609] Id. (citing Ex. NER001, MPR Testimony at 82).

[610] Id. (citing Tr. at 603 (Simons)).

[611] Id. (emphasis omitted).

[612] Ex. NRC091, Staff Response to Ex. INT051-R at 3–4.

[613] Id. at 6.

d. Findings of Fact and Board Analysis

As noted above, it is undisputed that the Seabrook aggregate and the LSTP aggregate differed in their chemical composition and structure. Although Dr. Saouma's concerns regarding concrete representativeness do not invalidate the CCI,[614] he has raised significant questions whether the chemical characteristics of the LSTP aggregates and the associated ASR gel was sufficiently representative of Seabrook concrete. In particular, the Board accepts Dr. Saouma's testimony that differences in aggregate chemistry affect crack width, cracking patterns, and expansion rates.[615]

The lack of concrete representativeness identified by Dr. Saouma may compromise the reliability of the extensometer threshold for extensometer installation of 1.0 mm/m (0.1%) (the extensometer threshold). Differences in crack width, cracking patterns, and expansion rates imply that monitoring of surface cracking using the CCI may be insufficient to reliably determine when extensometers should be installed to detect significant interior cracking of Seabrook structures. As explained previously, NextEra uses the CCI to monitor the effects of ASR on the surface of Seabrook structures and to determine when to install extensometers to monitor through-thickness expansion.[616] The monitoring methodology is derived from the LSTP.[617] For the LSTP specimens, the rate of expansion was approximately the same in all three directions until expansion reached [redacted] to [redacted] mm/m ([redacted]% to [redacted]%).[618] Thereafter, the LSTP specimens exhibited much greater expansion in the through-thickness direction than the in-plane

[614] Tr. at 426 (Saouma).

[615] Tr. at 981–82, 1001–02, 1082–83 (Saouma); Ex. INT032, Dr. Saouma Rebuttal Testimony at 12.

[616] See supra notes 448–450 and accompanying text.

[617] See Ex. NER001, MPR Testimony at 91–92, 122.

[618] Ex. NER020, MPR 0326-0062-88, Rev. 2, "Initial Expansion Assessment of ASR-Affected Reinforced Concrete Structures at Seabrook Station" (Mar. 2018) (FP101070, Rev. 1) at 5 [hereinafter Ex. NER020, MPR 0326-0062-88, Rev. 2] (non-public).

directions.[619] These observations led NextEra to conclude that using the CCI to monitor in-plane expansion sufficiently characterizes ASR development until at least 1.0 mm/m (0.1%) expansion, after which through-thickness monitoring by extensometers is required to monitor further ASR expansion.[620]

To ensure that through-thickness expansion will be adequately monitored before the limit is reached, which is critical for the adequate protection of public health and safety, the extensometer threshold must be accurate and reliable. Because the Board questions whether the LSTP specimens were sufficiently representative of Seabrook concrete,[621] we also question NextEra's reliance on the LSTP data to justify the 1.0 mm/m (0.1%) extensometer threshold. Absent a reliable threshold, through-thickness expansion near or even above the expansion limit may occur before the 1.0 mm/m (0.1%) extensometer threshold is reached, and therefore before the installation of extensometers. Thus, significant internal cracking may go undetected.[622] That would compromise the reliability of NextEra's structural capacity

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[619] Id. (non-public). The relationship between the CCI and through-thickness expansion observed in the LSTP specimens is illustrated in figure 4, Ex. NER003, MPR Testimony – Attachment 2 – Proprietary Appendix at 5 fig.4 [hereinafter Ex. NER003, MPR Testimony, Proprietary Appendix] (non-public). NextEra's monitoring program reflects its determination that Seabrook structures will exhibit a cracking pattern equivalent to that shown in figure 4, and that therefore extensometers need not be installed until in-plane expansion reaches 1.0 mm/m (0.1%). A different cracking pattern, however, could be problematical. If the CCI plateaus below 1.0 mm/m (0.1%), the through-thickness expansion rate is faster than shown in figure 4, or both, significant through-thickness expansion may occur before an extensometer is installed.

[620] Ex. INT019, MPR-4273 at B-4; Ex. INT021, MPR-4273 at B-4 (non-public).

[621] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 8, 9–17 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 8, 9–17; Ex. INT032, Dr. Saouma Rebuttal Testimony at 2.

[622] This concern is illustrated in figure B-2, Ex. INT021, MPR-4273 at B-5 fig.B-2 (non-public). The yellow rectangle, entitled "Approaching Expansion Limit Reevaluate Extensometer Threshold," represents possible locations with CCI less than 1.0 mm/m (0.1%) but through-thickness expansion greater than [redacted] mm/m ([redacted]%). Id.; Ex. INT019, MPR-4273 at B-5 fig.B-2.

evaluations, which are premised on through-thickness expansion remaining within the limits identified in the LSTP.[623]

Therefore, although C-10 agreed that the differing chemical characteristics of the aggregates and the associated ASR gel do not impact structural capacity,[624] the Board finds that those differing characteristics create substantial uncertainty as to whether the LSTP specimens were sufficiently representative of Seabrook concrete that they may serve as the basis of the CCI.

In support of CCI, NextEra and Staff witnesses testified that it is a generally accepted approach for measuring the rate of ASR expansion in concrete structures.[625] We are concerned, however, with the specific question whether the LSTP specimens are sufficiently representative of Seabrook concrete such that the crack widths, cracking patterns, and expansion rates observed in the test specimens justify the conclusion that significant through-thickness expansion will not occur in Seabrook seismic Category I structures as long as the CCI remains below the 1.0 mm/m (0.1%) extensometer threshold. General statements concerning the widespread acceptance of CCI are of little help in resolving that issue.

The Staff concluded that the LSTP was sufficiently representative of the structures at Seabrook, that interior cracking without surface cracking was not observed during the LSTP, and that the LSTP demonstrated that interior and surface cracking advanced together until surface cracking plateaued.[626] To the extent the Staff relied on those conclusions to justify the

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[623] Ex. INT010, Original LAR at PDF 19–20; Ex. NER001, MPR Testimony at 60.

[624] C-10's Redacted Supp. Proposed Findings of Fact and Conclusions of Law at 2.

[625] Ex. NRC001-R, Staff Testimony at 62 (citing Ex. NER013, U.S. Department of Transportation, Federal Highway Administration (FHWA), "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures" (FHWA-HIF-09-004) (Jan. 2010) [hereinafter Ex. NER013, FHWA Report]); see also Tr. at 319–20 (Simons), 323–27, (Bayrak), 482–85 (Bayrak).

[626] Tr. at 1132–34 (Buford); NRC Staff SOP at 57–62.

1.0 mm/m (0.1%) extensometer threshold, we are not persuaded. Dr. Saouma has convincingly testified that the acknowledged differences in aggregate chemistry affect crack width, cracking patterns, and expansion rates. For the reasons explained above, those differences cause the Board to question the reliability of the application of the 1.0 mm/m (0.1%) extensometer threshold to Seabrook structures.

Dr. Bayrak testified that more than 200 cores have been taken at Seabrook and there have been "zero occurrence[s] of a delamination crack."[627] We understand that the Staff refers to this evidence when it stated that "field evidence from cores that were removed at Seabrook in support of the installation of extensometers at both above and below ground locations has not shown any indications of structural concern in the concrete interior."[628] But we do not find evidence regarding the lack of an observed delamination crack to date sufficient to justify the 1.0 mm/m (0.1%) extensometer threshold for extensometer installation. Those are different issues. The concern remains that, because LSTP data was not sufficiently representative of Seabrook concrete, through-thickness cracking approaching the expansion limit may occur even though the extensometer threshold has not been reached.

In Appendix B to MPR-4273 (referred to as "Check 3"), MPR recommended a monitoring program to check the reliability of the extensometer threshold, albeit for different reasons than those urged by Dr. Saouma. As MPR explained, "NextEra has installed several extensometers in locations where in-plane expansion is less than 1.0 mm/m [0.1%]. This provides the opportunity to check consistency of expansion behavior over the entire range exhibited at

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[627] Tr. at 1097 (Bayrak). Delamination is "a crack between . . . two reinforcing mats." Ex. INT027, Dr. Saouma Pre-Filed Testimony at 17 fig.10. We address the issue of delamination cracks infra Part VIII.E.

[628] Ex. NRC001-R, Staff Testimony at 64.

Seabrook Station."[629] The Board understands that these are the "control extensometers" referred to in the SMP.[630]

MPR noted that "[f]or the [LSTP] specimens, the point at which expansion reoriented primarily in the through-thickness direction varied between specimens," even though the specimens "were essentially identical."[631] MPR recognized that "[d]ata from Seabrook Station may exhibit further variability from differences in configuration (e.g., wall thickness) and confinement (e.g., from deadweight)."[632] The Board finds Check 3 also necessary because Dr. Saouma has identified another potential source of variability that could also affect the reliability of the extensometer threshold—the differences in the chemistry of the LSTP concrete and Seabrook concrete that may affect crack width, cracking patterns, and expansion rates.

The Staff made Check 3 a mandatory condition when it granted the license amendment.[633] Pursuant to Check 3, NextEra will:

> [P]erform an engineering evaluation if the periodic expansion check identifies either of the following circumstances:
>
> - Any location with CCI less than [1.0] mm/m [0.1%] exhibits through-thickness expansion approaching the test program limit (i.e., greater than [mm/m] %). Such an observation would challenge the premise that an extensometer is not needed for locations with a CCI of less than [1.0] mm/m [0.1%]. The engineering evaluation would focus on the suitability of this criterion.
>
> - The general trend of expansion behavior at Seabrook Station significantly departs from the expansion behavior of the [LSTP] specimens. The expected trend at Seabrook Station is that in-plane and through-thickness expansion values will be comparable at lower

[629] Ex. INT019, MPR-4273 at B-5; Ex. INT021, MPR-4273 at B-5 (non-public).

[630] Ex. NER007, Seabrook [SMP] Manual Rev. 7, app. B, tbl.2. See Ex. NER001, MPR testimony at 150 (stating that extensometers were also installed in ten locations with ASR-induced expansion less than 1.0 mm/m (0.1%)).

[631] Ex. INT019, MPR-4273 at B-5; Ex. INT021, MPR-4273 at B-5 (non-public).

[632] Ex. INT019, MPR-4273 at B-5; Ex. INT021, MPR-4273 at B-5 (non-public).

[633] See Ex. INT024, Final SE at PDF 67–69.

> expansion levels and eventually transition to predominately through-thickness expansion.[634]

Check 3 will help resolve the Board's concern that the 1.0 mm/m (0.1%) extensometer threshold may not provide reasonable assurance of adequate protection of public health and safety. Nevertheless, we have identified a significant problem with the schedule for monitoring the control extensometers. Extensometers in Tier 3 areas, those locations where the 1.0 mm/m (0.1%) extensometer threshold has been exceeded, are to be monitored every six months.[635] But the extensometers installed where in-plane expansion is less than 1.0 mm/m (0.1%) (i.e., the control extensometers) will only be monitored for through-thickness expansion in 2025 and every ten years thereafter.[636] This schedule fails to provide adequate protection of public health and safety. As noted, one purpose of Check 3 is to determine whether the extensometer threshold of 1.0 mm/m (0.1%) will assure that extensometers will be installed before through-thickness expansion approaches the expansion limit. As Check 3 explains, the observation of an area with a CCI less than 1.0 mm/m (0.1%) that exhibits through-thickness expansion approaching the expansion limit "would challenge the premise that an extensometer is not needed for locations with a CCI of less than [1.0] mm/m [0.1%]."[637] That premise is fundamental to NextEra's monitoring program, and if it is incorrect, potentially damaging ASR expansion could go undetected for years.

There is no apparent reason why NextEra should not monitor the control extensometers every six months. The burden of doing so is not significant, given that monitoring only requires

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[634] Ex. INT019, MPR-4273 at B-5 to -6; Ex. INT021, MPR-4273 at B-5 to -6 (non-public).

[635] See Ex. INT010, Original LAR at PDF 65.

[636] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 3-1.7 to -1.8 (non-public); Ex. NER001, MPR Testimony at 62; Ex. INT019, MPR-4273 at B-5; Ex. INT021, MPR-4273 at B-5 (non-public). NextEra conducts in-plane monitoring of ASR expansion every thirty months for structures with less than 1.0 mm/m (0.1%) of ASR expansion. Ex. INT010, Original LAR at PDF 33 tbl.5.

[637] Ex. INT019, MPR-4273 at B-5 to -6; Ex. INT021, MPR-4273 at B-5 to -6 (non-public).

extensometer removal, measurement, and replacement. NextEra already monitors numerous extensometers in the Tier 3 areas every six months.[638] Monitoring the control extensometers every six months should ensure the prompt detection of any observation that would challenge the criterion (i.e., the threshold) for extensometer installation. In the event of such an observation, Check 3 requires NextEra to perform an engineering evaluation focusing on the continued suitability of that criterion.[639]

The Board therefore modifies Check 3 as follows:

> NextEra shall undertake the monitoring required by MPR-4273, Appendix B, Check 3, for control extensometers every six months, rather than in 2025 and every ten years thereafter.

The Board concludes that its modification of the Check 3 monitoring condition is necessary to provide reasonable assurance. With that modification, NextEra's CCI methodology satisfies the reasonable assurance standard despite the acknowledged differences in the chemical characteristics of the LSTP aggregate and the Seabrook aggregate.

One issue remains regarding the CCI. Dr. Saouma testified that NextEra should have only used crack width indexing in conjunction with advanced petrography.[640] He relied on the FHWA Guideline, which recommends a combination of crack width indexing and petrography for the preliminary investigative stage of an ASR assessment program and encourages its use during the later detailed study stage.[641] NextEra did perform crack width indexing and petrography during its preliminary investigation.[642] We agree with NextEra that for the purpose

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[638] See Ex. NER007, Seabrook [SMP] Manual Rev. at B-12 to -16 tbl.2 (non-public).

[639] Ex. INT019, MPR-4273 at B-4 to -6; Ex. INT021, MPR-4273 at B-4 to -6 (non-public).

[640] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 20.

[641] Id.; see Ex. NER013, FHWA Report at 3–6.

[642] Ex. NER004, SGH Testimony at 32, 35–36 (citing Ex. NER028, SG&H Report 110594-RPT-02, Rev. 1, "Damage Rating Index and ASR Rating" (Feb. 10, 2012) (FP100702)).

of determining whether surface cracking has reached the threshold for extensometer threshold, further petrography is not required because NextEra assumes that all cracking at Seabrook is caused by ASR unless proven otherwise.[643] We address the separate question whether petrography should be required for cores removed from Seabrook concrete infra Part VIII.E.

3. Test Specimen Scaling, Reinforcement, and Size

a. Motion in Limine

We find that discussion regarding the scaling of LSTP test specimens "is fairly encompassed by the description of" the admissible contentions that C-10 outlined in its petition.[644] Accordingly, NextEra's second Motion in Limine is denied in this respect.[645] We find section C.2.2 of Dr. Saouma's pre-filed testimony,[646] and all testimony related to prototype scaling, including specimen dimensions, loads, and boundary conditions within the scope of the reformulated contention.[647]

Stated briefly, Dr. Saouma testified that there is a significant problem with the scaling of LSTP test specimens, such that representativeness is jeopardized.[648] Dr. Saouma stated that "[a] significant problem with the [LSTP] testing is the failure to ensure that the relative

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[643] Ex. NER001, MPR Testimony at 151–52.

[644] Pilgrim, CLI-10-11, 71 NRC at 310.

[645] In NextEra's second Motion in Limine, it refers to Dr. Saouma's arguments as those pertaining to "scaled prototype" specimens. See NextEra MIL 2 at 15, 17. However, the specific section of Dr. Saouma's Pre-Filed Testimony is titled, "Specimen dimensions, loads and boundary conditions." See Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.2.2. Section C.2.2 of Dr. Saouma's Pre-Filed Testimony includes § C.2.2.2, which is titled "Boundary Conditions." Id. at 12–13. In this Initial Decision, we address all motion in limine issues relating to boundary conditions in this section and the following section. We address boundary conditions on the merits in the next section.

[646] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11–13.

[647] This includes: Ex. INT027, Dr. Saouma Pre-Filed Testimony §§ C.2.2, C.2.2.2; Ex. INT028, Dr. Saouma Rebuttal Testimony §§ D.3.2, D.4.1, D.4.2 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony §§ D.3.2, D.4.1, D.4.2.

[648] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11–12.

dimensions of the concrete beam that was tested were scaled to the prototype (i.e., the Seabrook reactor)."[649] Consequently, "the corresponding load will not be representative."[650] Dr. Saouma testified that the LSTP failed to account for boundary conditions.[651] Specifically, he claimed that "[i]n a test, the model must be subjected to the same conditions (support, restraints and load) as the prototype (Seabrook)."[652] Dr. Saouma also testified that the failure to model both in-plane and out-of-plane shear, in addition to the lack of proper scaling and boundary conditions, renders the LSTP not representative.[653]

NextEra asserted that Dr. Saouma's testimony as related to scaled prototype specimens attempts to shift the focus of the reformulated contention to an entirely new set of bases that could have been, but were not, raised at the outset of this proceeding.[654] It claimed that Dr. Saouma's concerns regarding scaled prototype specimens were not raised in C-10's Petition, and as a result, constitute new arguments.[655]

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[649] Id. at 11. Dr. Saouma explained that "[b]efore testing a model, one must first determine the largest dimension that can be accommodated in the laboratory (say x inches), and then determine the corresponding one in the prototype (in this case Seabrook) (most likely the thickness of the wall, say y inches) Then one would determine the scaling parameter alpha by taking the ratio of the two (y divided by x). This ratio should be respected in all other dimensional quantities (especially reinforcement location and ratios) for a correctly designed test. And the ratio will in turn govern the location of the reinforcement and the diameter of the reinforcement." Id. at 11–12.

[650] Id. at 12.

[651] Id. at 12–13.

[652] Id. at 12.

[653] Id.

[654] NextEra MIL 2 at 15–17.

[655] Id.

C-10 maintained that Dr. Saouma's arguments are properly before the Board[656] and that virtually every aspect of Dr. Saouma's testimony relates to the question whether the LSTP is representative of the progress of ASR at Seabrook over time.[657]

We first address NextEra's claims that Dr. Saouma's arguments are "new" and not part of the original list of bases. As stated above, supra Part VIII.A.2.a, we decline to take such a narrow view of the bases of the reformulated contention. Rather than introducing a new series of claims, we find that Dr. Saouma's explanations clarify issues identified in C-10's Petition and amplified in its Reply to the Staff.[658]

In its Reply, C-10 queried whether achieving the goal of obtaining representativeness would have been better served had NextEra removed "choice sections from the ASR-affected concrete in the unused Unit 2 at Seabrook Station[.]"[659] We find this argument sufficient to suggest that C-10 was concerned that the size, dimensions, and boundary conditions of the test specimens did not match Seabrook structures.

Representativeness is the crux of Contention D and, ultimately, of the reformulated contention. As explained in further detail, supra Part II.B, these material disputes challenge the adequacy of the LAR's monitoring program, acceptance criteria, and inspection intervals. NextEra asserted that the reformulated contention is limited to a narrow list of differences between the LSTP and the Seabrook structures.[660] Although we agree that these factors constitute some of the bases that form Contention D, as more fully explained above, they by no

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[656] See C-10 Opp. to MIL 2.

[657] Id. at 11–13.

[658] See La. Energy Servs., CLI-04-25, 60 NRC at 224 (approving licensing board's decision to consider information in petitioners' reply briefs that "legitimately amplified" issues presented in the initial petitions).

[659] C-10's Reply at 4.

[660] See NextEra MIL 2 at 2–3. Chief among those, age, and "the length of time ASR has propagated." C-10 Petition at 11.

means represent an exhaustive list.[661] Accordingly, we find that C-10's testimony on prototype scaling supports its existing arguments regarding the lack of representativeness and its implications for the LSTP.[662]

In our ruling on contention admissibility, we "concluded that Contention D was admissible as to the question of [the] representativeness of the [LSTP]."[663] NextEra witnesses explained that one of the primary reasons necessitating the use of the LSTP was that "published test results for selected limit states were from specimens that were too small to be considered representative."[664] Further, NextEra witnesses stated that the LSTP was conducted to obtain more representative data than was available in public literature.[665] Because scaling was a key parameter of representativeness, and a primary factor in initially conducting an LSTP, there clearly is a connection between scaling and representativeness.

Dr. Saouma alleged multiple errors in the design of the LSTP.[666] These errors relate to specimen dimensions, loads, and boundary conditions in the scaled prototype.[667] We find NextEra's assertion that Dr. Saouma's testimony falls outside the scope of issues

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[661] See supra Part VIII.A.2.a.

[662] See La. Energy Servs., CLI-04-35, 60 NRC at 623.

[663] CLI-18-4, 87 NRC at 104 (citing LBP-17-7, 86 NRC at 114).

[664] Ex. NER001, MPR Testimony at 138 ("A detailed comparison of the test specimens to the reference location is included in [Ex. NER026,] MPR-3757[.]").

[665] Id. at 54–55.

[666] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11–13.

[667] Id.

unpersuasive.[668] The issue of prototype specimen scaling is covered within the bases[669] of Contention D and the reformulated contention.[670]

Therefore, NextEra's Motion in Limine, with regards to prototype scaling, specimen dimensions, loads, and boundary conditions, is denied.

b. C-10's Prima Facie Case

Dr. Saouma identified the scaling of LSTP test specimens as a "significant problem with [the LSTP]" insofar as it jeopardized representativeness.[671] Specifically, Dr. Saouma stated that a proper scaling "ratio should be respected in all . . . dimensional quantities (especially reinforcement location and ratios)[.]"[672] If the test specimens are not scaled properly, Dr. Saouma stated, the specimens may exhibit "an erroneous failure mechanism (a beam may fail by bending, or a combination of bending and shear; the degree of which depends on the relative dimensions and location of shear reinforcement). Under these conditions, the corresponding load will not be representative."[673]

Dr. Saouma testified that his major concern is the Containment Enclosure Building (CEB).[674] The CEB is located outside the Containment Building and has a similar geometry.[675]

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[668] NextEra MIL 2 at 15–17.

[669] La. Energy Servs., CLI-04-35, 60 NRC at 623 ("Under our contention rule, [petitioners] are not being asked to prove their case, or to provide an exhaustive list of possible bases, but simply to provide sufficient alleged factual or legal bases to support the contention, and to do so at the outset.").

[670] See LBP-17-7, 86 NRC at 112–21, 125–27.

[671] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 11.

[672] Id. at 11–12.

[673] Id. at 12.

[674] Tr. at 612–13 (Saouma).

[675] Ex. NRC007, UFSAR §§ 3.8.1.1, 3.8.4.

This structure provides leak protection for the containment and protects it from certain loads.[676] The UFSAR described the CEB:

> The [CEB] is a reinforced concrete . . . cylindrical structure with a hemispherical dome. The inside diameter of the cylinder is 158 feet. The vertical wall varies in thickness from 36 inches to 15 inches; the dome is 15 inches thick. The inside of the dome is 5 [feet] 6 [inches] above the top of the containment dome.[677]

Dr. Saouma testified that the CEB should have been selected as the reference location because it is the "last barrier in case of seismic load," and therefore it constitutes the "Achilles' heel of the whole structure."[678] He also testified that a seismic load "is more likely to affect the CEB than a tunnel."[679]

Dr. Saouma further stated that an important difference between the test specimens and the CEB is that the test specimens were "about [redacted] scale ([redacted]-inch depth whereas the wall of a CEB is about 36 inches)."[680] Although he recognized that this is not unusual in component testing, Dr. Saouma stated that "given the brittle nature of shear failure and associated size effect, the shear strength in the CEB will be lower than the one from the LSTP."[681] According to a paper cited by Dr. Saouma, the size effect refers to "[t]he reduction in shear stress at shear failure as member depth of beams and slabs not containing stirrups increases[.]"[682] Dr. Saouma testified that "due to [the] size effect, the strength of a 36[-inch] deep beam ([modeling] the CEB

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[676] Id. § 3.8.1.1.

[677] Id. § 3.8.4.

[678] Tr. at 1046 (Saouma).

[679] Tr. at 1047 (Saouma).

[680] Ex. INT028, Dr. Saouma Rebuttal Testimony at 17 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 17.

[681] Ex. INT032, Dr. Saouma Rebuttal Testimony at 17.

[682] Ex. INT042, Bentz, E. C. (2005)[,] Empirical modeling of reinforced concrete shear strength size effect for members without stirrups. ACI structural journal, 102(2), 232. at 232 [hereinafter Ex. INT042, Bentz] (non-public). Stirrups provide through-thickness or triaxial reinforcement. See id.

wall) is about 26% lower than . . . a [redacted][-inch] one."[683] Because the LSTP used [redacted]-inch beams, Dr. Saouma stated, the LSTP may significantly overestimate the strength of a 36-inch deep beam. Thus, the LSTP [redacted]-inch beams would not be sufficiently representative of the below ground section of the CEB wall, which is 36 inches deep.

Dr. Saouma also testified that the reinforcement ratio of the test specimens is not representative of the CEB.[684] He stated that the reinforcement ratio may "be representative of the [B Electrical Tunnel]. Even so[,] the longitudinal reinforcement [is] higher; [redacted][%] instead of 0.6[%], but that reinforcement threshold is not at all close to what we have in the CEB where the reinforcement threshold is 0.34[%] in both direction[s]."[685]

Dr. Saouma's opinions are sufficient to meet C-10's burden to establish a prima facie case and the burden of proof on this scaling issue therefore shifts to NextEra.

c. NextEra and Staff Responses

NextEra used the B Electrical Tunnel as a reference location, claiming it is representative of other structures and was the location where NextEra first identified ASR.[686] MPR, NextEra's expert witnesses clarified, however, that the B Electrical Tunnel is not representative "of the walls of Containment and the lower portions of the CEB, which are triaxially reinforced[]."[687]

Regarding the test-model scaling issue raised by Dr. Saouma, NextEra witnesses testified that "one of the primary reasons for performing the LSTP was because published test results for selected limit states were from specimens that were too small to be considered

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[683] Ex. INT028, Dr. Saouma Rebuttal Testimony at 18 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 18.

[684] Tr. at 770 (Saouma).

[685] Tr. at 1046–47 (Saouma).

[686] Ex. NER001, MPR Testimony at 76–77.

[687] Id. at 77.

representative."[688] NextEra witnesses further testified that "[n]o scaling of the test specimen dimensions were required because the beam dimensions (thickness, reinforcing bar size, reinforcing bar spacing, concrete cover over reinforcing bars) were similar or identical to the reference location at the plant–i.e., the B Electrical Tunnel at Seabrook."[689]

NextEra witnesses asserted that "[b]ecause the scaling factor between the fabricated LSTP specimens and the B Electrical Tunnel is 1.0 (i.e., no scaling required), proportionate scaling for location of reinforcement and diameter of reinforcement was not necessary. The LSTP specimens used the actual reinforcement bar sizes and the actual reinforcement spacing . . . ."[690]

Staff witnesses testified that C-10's argument regarding scaling is immaterial because the LSTP specimens were almost full-scale compared to the bounding reference location, the B Electrical Tunnel:

> The length and width of the test specimens are the actual dimensions at the reference location and the height is that of a representative segment (or slice) of that location . . . . The test specimens included two-dimensional reinforcement mats using the same reinforcement size and spacing, one along each longitudinal face, and with no shear reinforcement[,] as in a typical wall at Seabrook.[691]

Staff witnesses also stated that "[b]ecause the LSTP supplements (rather than replaces) the design code, results from appropriately representative test specimens may be applied to reinforced concrete structures throughout Seabrook."[692]

It is undisputed that the LSTP concrete specimens were representative of the dimensions of the B Electrical Tunnel, the reference location. The more difficult question,

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[688] Id. at 138.

[689] Id.

[690] Id. at 139.

[691] Ex. NRC001-R, Staff Testimony at 52.

[692] Id. at 53.

however, is whether the tunnel is sufficiently representative or bounding of other Seabrook structures such that the data obtained from the LSTP specimens may appropriately be applied to those other structures.

Witnesses for both the Staff and NextEra "agreed" that it would be "reasonable" to use the B Electrical Tunnel to model ASR because "that was the worst ASR area."[693] The evidentiary record confirms that the tunnel has the highest through-thickness expansion measurements.[694]

In addition, NextEra witnesses testified that the CEB is actually more reinforced than the B Electrical Tunnel on which the test specimens are based[695] and that therefore the test specimens are bounding of the CEB. Specifically, the CEB is reinforced in both the in-plane direction and the through-thickness direction in the lower portions.[696] NextEra witness Mr. Sherman explained that "the lowermost portion of the CEB building where it's below [ground], where it's exposed to moisture, where we are seeing the [ASR] has through-[thickness] reinforcement."[697] This is in addition to the in-plane reinforcement of the test specimens.[698]

NextEra witness Dr. Bolourchi testified that the below ground area of the CEB has ASR.[699] He also testified that "all the below [ground] area[s] which . . . show any sign[s] of ASR . . . have through-thickness [reinforcement]. Above[-ground] is 15-inch concrete and there [is] no sign of ASR in there."[700] In addition, Dr. Bolourchi testified that the through-thickness

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[693] Tr. at 1047 (Buford).

[694] Ex. NER007, Seabrook [SMP] Manual Rev. 7, B-14 tbl.2 (providing pre-instrument through-thickness expansion measurements for locations in the B Electrical Tunnel) (non-public).

[695] Ex. NER001, MPR Testimony at 76–77, 99.

[696] Tr. at 700–02 (Sherman, Bolourchi).

[697] Tr. at 701 (Sherman).

[698] Tr. at 701 (Sherman); Ex. NER001, MPR Testimony at 99.

[699] Tr. at 954 (Bolourchi).

[700] Tr. at 1067 (Bolourchi).

reinforcement in the CEB is "one of the highest reinforcement[s] you can get in the through-thickness. Therefore, we are not relying on the concrete alone. We are relying on concrete plus steel. And the steel is not impacted by ASR."[701]

d. Findings of Fact and Board Analysis

We are not persuaded that there is no ASR-induced cracking in above ground areas of Seabrook structures, although this does not defeat a finding of reasonable assurance. One above ground area of the CEB, the wall inside and above the equipment hatch, has sufficient ASR cracking to require monitoring during outages.[702] Also, Staff witnesses acknowledged that extensometers had been installed in both the above and below ground locations at Seabrook.[703] Extensometers are usually installed in Tier 3 areas, those with a CCI measurement above 1.0 mm/m (0.1%).[704] Thus, ASR has not only been identified in above ground Seabrook structures but at sufficiently high levels to require the installation of extensometers. The areas of the CEB above an elevation of 22 feet do not have the triaxial reinforcement that is present in either the elevations below 22 feet or the below ground areas, and so they may be as susceptible to ASR-induced cracking as other above ground areas of Seabrook structures.[705]

Most of the above ground areas of the CEB do not have the triaxial reinforcement that is present in the below ground areas.[706] These areas may be as susceptible to the same ASR-

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[701] Tr. at 1064–65 (Bolourchi).

[702] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at B-4 to -5 tbl.1 (non-public).

[703] See Ex. NRC001-R, Staff Testimony at 64.

[704] Ex. INT010, Original LAR at PDF 33 tbl.5.

[705] Areas around CEB penetrations have additional reinforcement, with some penetrations such as the equipment hatch having triaxial reinforcement. Ex. INT015, Simpson Gumpertz & Heger, Inc., "Evaluation and Design Confirmation of As-Deformed CEB, 150252-CA-02," Revision 0, July 2016 (Seabrook FP#100985) Enclosure 2 to Letter SBK-L-16153, re: Seabrook Station (Sept. 30, 2016) at 26–29 [hereinafter Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB].

[706] Id.; Tr. at 701 (Sherman), 1067 (Bolourchi).

induced cracking as other above ground areas of Seabrook structures. Because of the lower relative humidity at the surface, Seabrook structures, including the CEB, may show little or no surface cracking but may have significant interior cracking, where the relative humidity is at or above the 80% threshold necessary for ASR reactivity.[707]

It is true, however, that the areas with the heaviest ASR cracking are generally below ground,[708] which provides some support for the selection of the B Electrical Tunnel as the reference location. But we must also consider the size effect described by Dr. Saouma.[709] As was explained above, the size effect causes lower shear strength for larger structures.[710] The critical issue, therefore, is whether the effect of the triaxial reinforcement in increasing shear strength is sufficient to offset the size effect.

Dr. Saouma cited Evan C. Bentz, "Empirical Modeling of Reinforced Concrete Shear Strength Size Effect for Members without Stirrups," which concluded that "[t]he size effect is real and shows decreasing shear stress at shear failure for larger beams that do not contain stirrups . . . [t]he percentage of reinforcement is important in equations that determine the shear strength of beams without stirrups[.]"[711] Thus, the Bentz article concludes that the size effect does not apply to beams with stirrups and that the amount of in-plane reinforcement is important.

The Seabrook CEB wall thickness varies from 36 inches at the base (El. -30 feet) to 27 inches from El. 11 feet to El. 40 feet and 15 inches above El. 40 feet.[712] The CEB is 228 feet

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[707] Ex. INT028, Dr. Saouma Rebuttal Testimony at 21–25 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 21–25.

[708] See Ex. NER007, Seabrook [SMP] Manual Rev. 7 at B-12 to -16 tbl.2 (non-public).

[709] Ex. INT028, Dr. Saouma Rebuttal Testimony at 17–18 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 17–18.

[710] See supra notes 680–683 and accompanying text.

[711] Ex. INT042, Bentz at 240 (non-public).

[712] Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 26–29.

tall.[713] Therefore, most of the CEB is approximately 2 feet thick or less, which is [redacted] the depth of the test specimens in the LSTP,[714] thus precluding any size effect concerns for a large part of the CEB.

The entire portion of the CEB that is 36 inches in depth includes transverse reinforcement (stirrups) in both the hoop (circumferential) and meridional (longitudinal or vertical) directions,[715] which is a structural geometry that was not addressed in the Bentz article.[716] Also, the in-plane reinforcement of the CEB in the hoop and meridional directions of the 36-inch thick portion of the CEB is greater than the reinforcement of the shear test specimens of the LSTP.[717]

At the hearing, NextEra witness Dr. Bayrak testified that "size effect is a factor well known in the shear community."[718] However, he also testified that this is accounted for in ACI 318-71 because "that version of the code mandates the use of a minimum quantity of transverse, through-thickness reinforcement in cases where the shear stress exceeds one-half of the concrete contribution to shear strength expression. The use of transverse reinforcement mitigates what's known as [the] size effect."[719] Dr. Saouma agreed with this, although he stated that "[the increase of shear strength from the reinforcement] is coming at a price of additional stresses which were not accounted for in the design process."[720]

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[713] Id. at 26.

[714] Id. at 26–29; see Ex. INT019, MPR-4273 at 3-2 tbl.3-1; Ex. INT021, MPR-4273 at 3-2 tbl.3-1 (non-public).

[715] Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 26–28.

[716] See Ex. INT042, Bentz at 240 (non-public).

[717] Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 26–28; Ex. INT019, MPR-4273 at 3-2 tbl.3-1; Ex. INT021, MPR-4273 at 3-2 tbl.3-1 (non-public).

[718] Tr. at 624 (Bayrak).

[719] Tr. at 625–26 (Bayrak).

[720] Tr. at 629 (Saouma).

Given the transverse reinforcement, which mitigates the size effect, the higher in-plane reinforcement of the 36-inch thick portion of the CEB, the small size of the 36-inch segment, and the fact that the wall thickness of a large majority of the CEB is 15 inches (which is much less than the wall thickness of the LSTP test specimens), the Board finds, based on a preponderance of the evidence, that the size effect will not reduce the shear response of the CEB structure relative to the LSTP test specimens.

With respect to Dr. Saouma's concern regarding the [redacted] reinforcement of some test specimens,[721] NextEra witnesses testified that while "[t]he LSTP specimens used the actual reinforcement bar sizes and the actual reinforcement spacing[,]" there was one exception for the "spacing of the longitudinal reinforcement in the shear specimens, which used additional rebar in the longitudinal direction to ensure a shear failure[.]"[722] NextEra witnesses further testified that the "use of additional longitudinal reinforcing bars in the shear test specimens provided additional flexural capacity, and therefore ensured that failure during load testing would be in shear rather than flexure."[723] MPR-3757 addresses the use of the longitudinal and perpendicular reinforcement spacing for the shear test specimens.[724]

Similarly, Staff witnesses testified that the LSTP was not a model test; rather:

> [I]t was a full-scale load test, consistent with the test methodology on which the ACI 318-71 empirical code equations for structural capacity (for strength limit states such as flexure and shear) were developed, created to determine the impact of ASR on structural capacity for specific limit states. The individual tests were designed to ensure that the failure mode of each test specimen supports the limit state of interest in that test. The purpose of the tests was . . . to validate the applicability and/or limitations of the ACI 318-71 code equations for estimating structural capacity for critical limit states for ASR-affected reinforced concrete structures at Seabrook.[725]

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[721] Tr. at 1046–47 (Saouma).

[722] Ex. NER001, MPR Testimony at 139.

[723] Id. at 139–40.

[724] See Ex. NER026, MPR-3757 § 3.2.3 (non-public).

[725] Ex. NRC001-R, Staff Testimony at 53–54.

We find the scaling, reinforcement, and size of the specimens in the LSTP reasonable and sufficient to provide reasonable assurance of adequate protection of public health and safety.

4. Boundary Conditions

a. Motion in Limine

NextEra argued that Dr. Saouma's testimony regarding dimensions and boundary conditions introduces new challenges to the execution of the LSTP and deficiencies in the LAR that were not advanced in the original Petition.[726] Specifically, NextEra seeks to exclude section C.2.2.2 from Dr. Saouma's pre-filed testimony, as well as sections D.4.1 and D.4.2 from Dr. Saouma's rebuttal testimony, claiming that he raised new arguments that could have been raised at the outset and are unrelated to the reformulated contention.[727] For the same reasons addressed earlier, supra Part VIII.A.3.a, the Board denies the Motion in Limine in this respect and holds section C.2.2.2 of Dr. Saouma's pre-filed testimony and sections D.4.1 and D.4.2 of Dr. Saouma's rebuttal testimony are within the scope of this proceeding.[728]

b. C-10's Prima Facie Case

Dr. Saouma suggested that NextEra made errors in the design of the LSTP regarding the specimen boundary conditions.[729] Specifically, he stated that "[i]n a test, the model must be subjected to the same conditions (support, restraints and load) as the prototype (Seabrook)."[730] He further stated that "the [LSTP] tests modeled only the [out-of-plane] shear and not the in-

[726] NextEra MIL 2 at 17–18.

[727] Id.

[728] Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.2.2.2 generally critiqued the boundary conditions used in the LSTP, whereas Ex. INT032, Dr. Saouma Rebuttal Testimony § D.4.1 stated that the lack of testing for in-plane shear is a concern, and § D.4.2 developed the argument that the lack of in-plane shear testing is a concern by stating the CEB will be affected by in-plane shear forces during a seismic excitation.

[729] Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.2.2.2.

[730] Id. at 12.

plane [and that] . . . [o]ut-of-plane results may not be directly applicable to in-plane."[731] Dr. Saouma also stated that axial forces from in-situ boundary conditions can negate the prestressing effect observed in ASR-affected reinforced concrete and that the "prestressing [effect] may be dwarfed by . . . axial loads [from gravity] and . . . cannot be relied upon."[732] Thus, he testified that as a result of these deficiencies "the [LSTP] cannot be seen as a representative model of the prototype (Seabrook)."[733]

Dr. Saouma's testimony provides a plausible analysis to support his opinion. C-10 has therefore satisfied its burden to present a prima facie case.

c. NextEra and Staff Responses

Regarding boundary conditions, NextEra witnesses testified that "the test setups for the Shear and Reinforcement Anchorage Test Programs used a point loading arrangement."[734] NextEra witnesses acknowledged that "[t]his loading is different than the conditions for some structures at Seabrook, which have uniform loading due to hydrostatic loading from the exterior of the structure, the weight of the structure, and the global application of potential loads (e.g., seismic)."[735] Thus, "[t]he test setups were not aimed at replicating boundary conditions (i.e., load or deformation compatibility) at Seabrook. Rather, the test setups were adopted since they are industry standard tests for studying shear behavior and reinforcement anchorage."[736]

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[731] Id.

[732] Id. at 13.

[733] Id.

[734] Ex. NER001, MPR Testimony at 74 (citing Ex. NER015, MPR-3848, Rev. 0 "Seabrook Station, Approach for Shear and Reinforcement Anchorage Testing of Concrete Affected by Alkali-Silica Reaction" (Apr. 2013) (FP100818) § 4.3 [hereinafter Ex. NER015, MPR-3848] (non-public)).

[735] Id.

[736] Id.

NextEra witnesses stated that "[r]eplication of the in-situ conditions would have been excessively complex and is ultimately unnecessary for reasonable assurance. Considering the variety of loading and boundary conditions present at Seabrook, it is not practical or even possible to replicate every location."[737] As NextEra witness Dr. Bayrak put it, "having to focus on replicating all aspects of everything at every location would result in building another nuclear power plant."[738]

Dr. Bayrak further emphasized that "ACI 318-71 expressions do not aim to replicate the boundary conditions for the myriad structures in which the design expressions [(i.e., design equations)] are used. Instead, ACI 318-71 presents design expressions that can uniformly be applied to concrete structures."[739] Following the approach of ACI 318-71, "the LSTP used the most severe loading and boundary conditions for the limit states of interest and were consistent with the approaches used to develop the ACI Code equations of interest, which provide the design basis for the plant."[740]

NextEra witnesses testified:

> The test configuration (simply supported beam with point loading) is typical for testing used to develop empirical ACI code expressions. The experimental design is for separate effects testing and deliberately omitted additional forces (e.g., axial forces) that might impact the results, which is consistent with industry practices for shear testing. For Seabrook, additional forces due to building configuration or other loads (e.g., seismic) are accounted for in the SEM and did not need to be simulated in the load tests.[741]

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[737] Id. at 74–75.

[738] Tr. at 428–29 (Bayrak).

[739] Ex. NER001, MPR Testimony at 75 (citing Ex. NER015, MPR-3848 § 4.3 (non-public)).

[740] Id.

[741] Id. at 98 (citing Ex. NER015, MPR-3848 § 4.3 (non-public); Ex. NRC051, Report of ACI-ASCE (American Society of Civil Engineers) Committee 326, "Shear and Diagonal Tension" (1962) (non-public)).

With respect to Dr. Saouma's concern regarding the tests not modeling in-plane shear, NextEra witnesses further testified:

> Out-of-plane shear is perpendicular to the plane of a wall (e.g., a force pushing on the wall surface). In-plane shear occurs in the plane of a wall (e.g., a force pushing down from the top of the wall). In the context of Seabrook, out-of-plane shear is not resisted by reinforcement, whereas in-plane shear is.[742]

According to NextEra, it "demonstrated through review of published literature that one-way shear with reinforcement was not a concern for Seabrook . . . [h]ence, there was no need to evaluate in-plane shear as part of the LSTP."[743]

Staff witnesses agreed that "the LSTP did not test for the in-plane shear mode because the out-of-plane shear failure is bounding" of in-plane shear.[744] Staff witnesses, like those of NextEra, judged the out-of-plane shear failure mode "to be more critical than [the] in-plane shear mode."[745] Staff witnesses noted that under the ACI 318-71 code the "nominal permissible out-of-plane shear stress in concrete is . . . $2*\sqrt{f'_c}$" which contrasts with the greater "allowable total shear stress of $10*\sqrt{f'_c}$ for in-plane shear[,] . . . [w]here f'_c is the specified minimum concrete compressive strength[]."[746]

For C-10's part, Dr. Saouma testified that "[t]he fact that the ACI 318-71 code allows 10 times the square root of the compressive strength for [in-plane] shear, as opposed to only two times for [out-of-plane], is irrelevant."[747] He further testified that:

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[742] Id. at 140.

[743] Id. (citing Ex. NER018, MPR-3727 at 6-8 tbl.6-4; Ex. NER019, Bayrak White Paper at 12 tbl.4 (non-public)); Ex. NRC075, Dean J., Deschenes, et. al., "ASR/DEF-Damaged Bent Caps: Shear Tests and Field Implications," Technical Report No. 12-8XXIA006 summarizing work conducted for the Texas Department of Transportation at Ferguson Structural Engineering Laboratory, The University of Texas at Austin (August 2009) § 7.2.2 [hereinafter Ex. NRC075, Deschenes, et al.].

[744] NRC Staff SOP at 51 (citing Ex. NRC001-R, Staff Testimony at 53–55).

[745] Ex. NRC001-R, Staff Testimony at 54–55.

[746] Id. (citing Ex. NRC049, ACI 318-71 §§ 11.4.1, 11.16.5 (non-public)).

[747] Ex. INT032, Dr. Saouma Rebuttal Testimony at 18.

> [T]he relative loss in strength will be equal to the square root of the fraction of the loss because the 2 and the 10 cancel out[]. For instance, if the original compressive strength is 100 (never mind the units), and due to ASR the compressive drops to 70, the loss in shear strength for both in-plane and [out-of-plane] will be equal to the square root of 70 divided by 100 (0.83).[748]

Therefore, he stated that "the concrete deterioration of the in-plane shear should be accounted for . . . [because] the analysis of the container is not accounting for this loss."[749]

In other testimony, however, Dr. Saouma appeared to recognize the greater importance of out-of-plane shear:

> Ultimately, the major concern about the reduced shear strengths is due to the lateral load. There is not really a major concern about the safety of the structure due to the gravity load, the vertical load. It assumes there will be a lateral load due to seismic activity. This is where the problem occurred. Because to resist a lateral load is the shear strength of the concrete.[750]

NextEra witnesses testified that NextEra:

> [D]id consider axial compression during planning of these tests. The ACI [318-71] shear design methodology recognizes that axial compression improves the shear strength of reinforced concrete, and conversely, axial tension weakens the shear strength of reinforced concrete. In this context, it is important to recognize two facts: (1) There is no reason to believe that the beneficial effects of axial compression to shear strength would be any different for ASR-affected concrete, particularly in view of the publicly available test data, and (2) restraint provided by the actual structural configurations present at Seabrook introduces axial restraint (i.e., compression) forces that would benefit shear strength, thus making the testing conservative (because the test setup did not have the benefit of being part of a larger structure that provides restraint). This effect is taken into account by the structural analysis methodology. Accordingly, it would not have been appropriate to also include axial compression forces in the experimental program.[751]

Staff witnesses testified that they agreed that NextEra did not need to test for axial forces caused by deadweight, explaining that "these axial forces are compressive and have a

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[748] Id. (emphasis omitted).

[749] Id.

[750] Tr. at 361 (Saouma).

[751] Ex. NER001, MPR Testimony at 141–42.

beneficial effect on structural capacity in flexure and shear for in-situ structures such as those at Seabrook."[752]

d. Findings of Fact and Board Analysis

The Board agrees with NextEra that the variety of loading and boundary conditions present at Seabrook makes it impractical to replicate every location of concern. The Board also agrees with NextEra that the ACI 318-71 design equations do not aim to replicate the boundary conditions for each of the large number of structures to which they are applied. Instead, ACI 318-71 can be uniformly applied to concrete structures even though there may be variations within the specific configuration of structural components.

The Board concludes that NextEra has met its burden to show by a preponderance of the evidence that the LSTP was sufficiently representative of the boundary conditions of Seabrook structures. It was reasonable for the LSTP to focus on out-of-plane shear because out-of-plane shear failure is bounding of in-plane shear failure, and the test configuration provides a conservative evaluation of the structural capacity of Seabrook. We also conclude that NextEra did not need to test for axial forces due to deadweight because those forces have a beneficial effect on structural capacity in flexure and shear. Therefore, it was conservative to exclude those forces from the test program.[753]

5. Effect of Reinforcement (Use of Original Material Properties)

It is undisputed that ASR degrades the material properties of concrete, including compressive strength, elastic modulus, and tensile strength.[754] "Because concrete material

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[752] Ex. NRC001-R, Staff Testimony at 55.

[753] Although not part of the LSTP, the specific configuration and boundary conditions of each Seabrook structure affected by ASR and its foundation are included in the SEM and are thus accounted for in the calculation of the structural demand for each structure. The methodology used to calculate structural demand is outside the scope of the proceeding. See infra Part VIII.F.1; see supra note 741 and accompanying text.

[754] Ex. INT027, Dr. Saouma Pre-Filed Testimony, at 6; Ex. INT031, Dr. Saouma Review of Selected Documents at 12–14; Ex. NER001, MPR Testimony at 39 ("ASR can produce cracking

properties are used as direct inputs to Code equations for determining structural capacity, a decrease in concrete material properties implies a corresponding decrease in calculated structural capacity."[755] Relying on the LSTP, however, NextEra concluded that "in reinforced concrete, the presence of reinforcing bars and the consequent 'chemical prestressing effect' causes the structural performance of ASR-affected reinforced concrete to depart from what would be calculated using the ASR-affected material properties as inputs to the code expressions."[756] NextEra decided it could use the original, non-degraded material properties as inputs to the code equations for determining structural capacity when ASR-induced expansion is within the limits of the LSTP.[757] C-10 challenged this determination.[758]

a. Motion in Limine

NextEra moved to exclude testimony on the use of original material properties claiming these arguments are new and beyond the scope of the reformulated contention.[759] We deny NextEra's motion in this regard. In Contention B, one of the bases of the reformulated contention, C-10 challenged NextEra's reliance on the beneficial effect of the confinement provided by reinforcement and the resulting chemical prestressing effect. Contention B, as admitted by the Board, alleges that "[t]he LAR misconstrues expansion occurring within a reinforced concrete structure due to the [ASR] because any mitigation of lost structural capacity,

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in concrete, and eventually causes degradation of its material properties–compressive strength, elastic modulus, tensile strength, etc.–as measured from typical tests conducted on cylinders or cores."); Ex. NRC001-R, Staff Testimony at 7 ("[ASR] cracking degrades the mechanical material properties of the affected concrete.").

[755] Ex. NER001, MPR Testimony at 39–40 (citing Ex. NRC049, ACI 318-71 § 11.4 (non-public)).

[756] Id. at 41.

[757] Id. at 60.

[758] See infra Part VIII.A.5.b.

[759] NextEra MIL 2 at 21–24.

due to reinforcement, is temporary and unpredictable."[760] In support of Contention B, C-10 directly disputed the LAR's claim that, although ASR reduces the material properties of concrete, this "does not necessarily result in a corresponding decrease in capacity of a reinforced concrete structure [because] ASR-induced expansion in reinforced concrete has a prestressing effect that mitigates the loss of structural capacity that would be assumed based on the change in material properties."[761]

If C-10 is correct, then NextEra's structural evaluations, which assume undegraded material properties because of the beneficial effect of reinforcement as long as ASR remains within the expansion limits,[762] would be based on an incorrect assumption derived from the LSTP. According to NextEra witnesses, the LSTP confirmed that the original code capacities and standard methods of computing stiffness could be used in structural analyses and evaluations on the capacity side of the finite element analysis (FEA).[763] Because NextEra used a conclusion from the LSTP to determine which material properties to use in the FEA to assess capacity, C-10's testimony challenging the use of original material properties is within the scope of the proceeding. If the LSTP is found not to be sufficiently representative, that would call into question any conclusions stemming from the LSTP, such as the use of the original material

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[760] LBP-17-7, 86 NRC at 107.

[761] Ex. INT010, Original LAR at PDF 10; C-10 Petition at 4–5; see also Ex. NER001, MPR Testimony at 38 ("Prestressing of concrete refers to the approach of applying a compressive load to improve the tensile capacity of the concrete member. When the concrete member is in service, if tensile loads are applied, the compressive prestress (i.e., pre-compression) must be completely overcome before a portion of the member is exposed to net tension, at which point cracking may ensue. Because concrete is much stronger in compression than tension, prestressing can improve in-service performance for certain applications.").

[762] See Ex. INT014, MPR-4288 at 2-3 (non-public); Ex. INT012, MPR-4288 at 2-3.

[763] Ex. NER004, SGH Testimony at 17–18 ("We evaluated the LSTP information regarding stiffness and capacity in much the same way that we evaluated other academic literature and testing programs. We considered these conclusions (i.e., that stiffness and capacity are not impacted by ASR within the limits of testing) in developing the baseline assumption in the SEM that existing code capacities and standard methods of computing stiffness can be used in structural analyses and evaluations."). The FEA is explained supra Part II.A.

properties to determine structural capacity. And if the use of original material properties caused NextEra to overestimate the capacity of Seabrook seismic Category I structures, its support for the LAR would be undermined. Therefore, NextEra's Motion in Limine is denied regarding the use of original material properties.

b. C-10's Prima Facie Case

Dr. Saouma stated that "ASR will reduce the tensile strength and the elastic modulus of concrete . . . by as much as 60%. As to the compressive strength, it has long been assumed that it is not affected by ASR; however there is recent evidence to the contrary . . . ."[764] He also stated that "[t]he concrete material is degraded by ASR (by virtue of its correlation to the tensile strength)[.]"[765] He further testified that the elastic modulus is reduced by the deteriorated nature of the existing concrete.[766] Dr. Saouma also testified that ASR undoubtedly affects the elastic modulus, which will "result in larger displacements, and in turn [an] increased likelihood of cracking[.]"[767] He also stated that "ASR will reduce the tensile and shear strength of concrete while increasing [its] propensity [for] larger deformation[s]. This in turn increases the likelihood of cracking and reduces the ability of a structure to resist [a] lateral seismic load."[768]

Although Dr. Saouma stated that "[c]oncrete shear strength will decrease rather than increase because of ASR," he acknowledged that "[r]einforced concrete . . . will not have a decrease in shear strength because of [the] prestressing effect[.]"[769] Dr. Saouma stated that the

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[764] Ex. INT031, Dr. Saouma Review of Selected Documents at 13 (citations omitted).

[765] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 26.

[766] Id. at 25 ("[T]he elastic modulus should have been reduced, and this in turn will reduce the stiffness of the [nuclear containment vessel structure]. Indeed [Ex. NRC049, ACI 318-71 § 19.2.2.1 (non-public)] has an approximate equation for the elastic modulus in terms of the compressive strength. However, this cannot be valid for a deteriorated concrete as it is outside the assumptions of the ACI equation."); Tr. at 950 (Saouma).

[767] Ex. INT031, Dr. Saouma Review of Selected Documents at 15; see Tr. at 314–15 (Saouma).

[768] Ex. INT031, Dr. Saouma Review of Selected Documents at 14.

[769] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 17.

reduction in concrete shear strength due to ASR "is a universal material characteristic that can be used inside a finite element program's constitutive relation (a) to relate stress to strain; and (b) to define a yield surface or failure load."[770] Dr. Saouma recognized the need to take into account the effect of confinement on the degraded material properties.[771] Still, he testified that this should be done as part of the FEA,[772] and he cited examples where researchers were able to capture "increasing strengths as a result of chemical [prestressing] of ASR."[773]

Dr. Saouma's rebuttal testimony, which responded to NextEra's claim that the chemical prestressing effect is fundamentally beneficial, explained that "[w]hile MPR state[d] that 'the beneficial effects of confinement are recognized in the structural engineering community,' its potentially adverse effects are also recognized[.]"[774] He explained that "[t]he real possibility of excessive steel stresses resulting in premature fracture or yielding was also reported . . . . Indeed, in this paper, it is shown that 'chemical prestressing' has caused the rupture of steel and thus partial collapse of a bridge."[775]

In further support of his opinion, Dr. Saouma cited an FSEL study prepared for the Texas Department of Transportation that identified "more than thirty cases of fractured

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[770] Id. In an FEA, constitutive relation(s) are used for the prediction of specific physical phenomena in a finite element method or other numerical analysis, such as the response of a material to an applied force.

[771] Tr. at 651 (Saouma) ("[A]ny semi-reasonable finite element code would be able to capture the interaction between the material and the surrounding [reinforcement] and the chemical [prestressing].").

[772] Id.

[773] Id.

[774] Ex. INT032, Dr. Saouma Rebuttal Testimony at 19.

[775] Id. (citing Ex. INT043, Miyagawa et al., Fracture of Reinforcing Steels in Concrete Structures Damaged by Alkali-Silica Reaction. Journal of Advanced Concrete Technology, 4(3), 339-355 (2006)). "Yielding of the reinforcing bars refers to permanent deformation of the steel, which occurs when deflection of the beam produces stresses in the reinforcing bars that reach their yield strength. This failure mode is preferred for structural design because it is more gradual than the sudden brittle failure of concrete that could occur with failure of reinforcement anchorage at the lap splice." Ex. NER001, MPR Testimony at 102–03.

reinforcements . . . in bridges and other structures" affected by ASR.[776] The FSEL study noted that this discovery by Japanese researchers led them to reassess the impact of ASR on structural safety and serviceability stating that "[a]s long as reinforcing steels are not broken due to ASR-caused expansion, the safety of a structure is considered not to be seriously compromised. However, the safety of a structure becomes questionable when the confinement of the concrete becomes degraded due to fracture of reinforcing steel bars (Miyagawa 2006)."[777] Further, the FSEL study stated that "[p]erception of ASR as structurally harmless deterioration persisted until the recent discovery of fractured reinforcement in the deteriorated structures of Japan. It was immediately recognized that the ASR-induced fracture of reinforcement would lead to a sudden loss of structural capacity."[778]

Dr. Saouma acknowledged that prestressing reduces the impact of degraded material properties on structural capacity.[779] However, he also testified that the prestressing effect is accompanied by increases in tensile and compressive stresses that were not accounted for in the design process.[780] He further stated that strain gauges[781] should have been placed on the LSTP's shear beam "to assess and quantify the adverse effects of the chemical prestressing[.]"[782]

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[776] Ex. INT032, Dr. Saouma Rebuttal Testimony at 19 (citing Ex. NRC075, Deschenes, et al. at 25–26).

[777] Ex. NRC075, Deschenes, et al. at 26.

[778] Id. at 28.

[779] Tr. at 627–29, 829 (Saouma).

[780] Id.; Ex. INT032, Dr. Saouma Rebuttal Testimony at 20.

[781] Ex. NER004, SGH Testimony at 37 ("[O]ngoing expansion is monitored using demountable mechanical strain gauges that more precisely measure the distance between gauge pins permanently installed in the concrete.").

[782] Ex. INT032, Dr. Saouma Rebuttal Testimony at 21.

We conclude that C-10 satisfied its burden to make a prima facie case on the issues raised by Contention B and incorporated in the reformulated contention.

c. NextEra and Staff Responses

NextEra witnesses acknowledged that "ASR in reinforced concrete still causes a reduction in material properties like unreinforced concrete."[783] In reinforced concrete, however, NextEra witnesses stated that "the presence of reinforcing bars and the consequent 'chemical prestressing effect' causes the structural performance of ASR-affected reinforced concrete to depart from what would be calculated using the ASR-affected material properties as inputs to the code expressions."[784] According to NextEra witnesses, the LSTP showed that "because of the interaction between concrete and reinforcing in a reinforced concrete member, the strength and stiffness of the overall members are not reduced within certain ASR strain limits."[785]

NextEra concluded that the original elastic modulus can be used because the "[u]nreduced design material stiffness properties can adequately represent ASR-impacted reinforced concrete sections of the CEB structure."[786] NextEra witnesses also emphasized that:

> [W]hile ASR may degrade both the strength and stiffness of the unconfined concrete material, the research has demonstrated that, within certain ASR strain limits, neither the strength nor the stiffness of structural elements is degraded below that predicted by code equations and principles of structural mechanics if original concrete properties are used.[787]

[783] Ex. NER001, MPR Testimony at 41.

[784] Id.

[785] Ex. NER004, SGH Testimony at 61–62.

[786] Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 22.

[787] Ex. NER004, SGH Testimony at 59 (citing Ex. INT019, MPR-4273; Ex. NER001, MPR Testimony at 58–60) (emphasis omitted).

For example, Table 4 of the ISE document provides the "[l]ower bound residual mechanical properties as percentage of values for unaffected concrete at 28 days."[788] The ISE document notes that:

> It is emphasized that the residual strength and stiffnesses in actual structures will be modified from the figures in Table 4 [which show reductions in properties due to ASR]. This is because the concrete in actual structures is generally restrained by adjacent material and is in a biaxial or triaxial stress state. These effects will tend to reduce the damage to the concrete and increase its residual mechanical properties.[789]

On this basis, NextEra witnesses testified that the original concrete material properties can appropriately be used in the structural evaluations within the limits defined by the LSTP.[790]

Staff witnesses largely supported NextEra's testimony and stated that:

> Because of the in-situ confinement and the interaction between the reinforcing steel and the concrete, the load-carrying behavior of ASR-affected structures is generally expected to be better than would be expected from the material properties measured on test specimens or cores. Therefore, it is important that reinforced concrete structures affected by ASR be evaluated based on the impact on structural strength of a reinforced concrete composite system, and not necessarily on individual concrete material properties obtained by extracted core samples.[791]

Thus, according to Staff witnesses, "the results of the LSTP demonstrate that there is no impact on [the] in-situ structural capacity of reinforced concrete components within the expansion levels identified in the [LSTP]."[792] In sum, both NextEra and the Staff agreed that it is not necessary to input the degraded material properties in the FEA as long as ASR-induced expansion is within the expansion limits of the LSTP.

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[788] Ex. NER012, ISE Structural Effects of [ASR] at 14 tbl.4 (non-public).

[789] Id. at 14 (non-public).

[790] Ex. NER001, MPR Testimony at 54.

[791] Ex. NRC001-R, Staff Testimony at 9.

[792] Id. at 70; Ex. INT024, Final SE at PDF 40.

With respect to the NRC's regulations, Staff witnesses testified that the relevant issue is the effect that a degradation mechanism may have on structural properties rather than material properties.[793] Therefore, Staff witnesses stated that the relevant question is whether a reinforced concrete structure at Seabrook, as a whole, is capable of fulfilling its intended safety functions despite the presence of ASR.[794] In other words, "[t]o determine whether an ASR-affected reinforced concrete structure or structural component remains capable of fulfilling its intended functions, it is the structural strength (as a reinforced concrete composite system) that matters and not individual material strengths."[795]

In disputing Dr. Saouma's claims in his testimony that NextEra confused material strength with structural strength,[796] Staff witnesses testified that:

> Dr. Saouma is referring to the material properties of concrete (e.g., compressive strength, tensile strength, etc.). When affected by ASR, the material properties of concrete are degraded. This is well known in existing ASR literature and the results of the LSTP showed the expected reductions in material properties. NextEra acknowledged these results; however, the entire point of the LSTP was to demonstrate that although concrete material properties may be reduced, the structural performance of the reinforced concrete member can still be conservatively estimated by the design basis code equations. Thus, NextEra is not confusing material strength with structural strength, it is relying on the LSTP results to demonstrate that structural strength is unaffected as long as the expansion remains below the identified limits from the LSTP, regardless of the reductions in material strength.[797]

In response to Dr. Saouma's testimony that the chemical prestressing effect is accompanied by increases in tensile and compressive stresses that were not accounted for in the design process, NextEra witness Dr. Bayrak testified that "[i]n the context of axial compressive strength of an element, it is, in fact, true that . . . the chemical [prestressing effect] .

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[793] Ex. NRC001-R, Staff Testimony at 8–9.

[794] Id.

[795] Id.

[796] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 17.

[797] Ex. NRC001-R, Staff Testimony at 58.

. . offers a lot of different benefits here and there is a negative impact," but Dr. Bayrak also stated that the negative "impact has been accounted for in the SGH analyses."[798] With regard to Dr. Saouma's concern that strain gauges should have been placed on the LSTP's shear beam specimen, Dr. Bayrak testified that "strain gauges typically fail" when used in tests such as those conducted in the LSTP that accelerate the rate of ASR progression.[799]

d. Findings of Fact and Board Analysis

The parties agreed on four issues. First, that ASR degrades the material properties of concrete, including compressive strength, elastic modulus, and tensile strength. Second, despite the acknowledged degrading effect of ASR, reinforced concrete will not have a decrease in shear strength because of the chemical prestressing effect. Third, any calculation of structural capacity must consider the effect of prestressing on the capacity of Seabrook structures. Finally, chemical prestressing produces both beneficial and negative impacts.

The parties disagreed, however, on how the prestressing effect should be evaluated. NextEra chose to use the original material properties, not the degraded properties, as inputs to the code equations used to calculate structural capacity. It asserted it did so because the resulting calculations of structural capacity were consistent with the results of the LSTP, which showed no loss of structural capacity within the identified expansion limits.[800] On the other hand, Dr. Saouma prefers that the degraded material properties be incorporated into the FEA as structural capacity and that it captures the beneficial effect of prestressing.[801] NextEra also

[798] Tr. at 630 (Bayrak).

[799] Tr. at 631 (Bayrak).

[800] Ex. NER004, SGH Testimony at 61–62; Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 22; Ex. NRC001-R, Staff Testimony at 70.

[801] Tr. at 650–55 (Saouma).

chose to capture the interaction between the rebar and the expanding concrete through the testing of actual concrete specimens.[802]

The Board finds that neither approach has any obvious superiority to the other. Dr. Saouma's approach would utilize degraded material properties taken directly from the testing of Seabrook cores, which would avoid the need to rely on the LSTP results that raise the various questions about representativeness.[803] NextEra witness Dr. Bolourchi testified, however, that Dr. Saouma's modeling approach would require the evaluation of numerous additional parameters and instrumentation of the Seabrook structures, not just testing of core borings.[804] NextEra's approach has the advantage of relying on actual testing to determine the effect of the rebar on the expanding concrete. In the absence of a reason to prefer Dr. Saouma's recommended approach, the Board concludes that it was reasonable and consistent with NRC regulations for NextEra to use the nondegraded, original concrete material properties and code equations in the structural capacity calculations.

The other area of disagreement is the potential for ASR to cause or contribute to the fracture or yielding of reinforcing steel bars and a resulting loss of structural capacity. While Dr. Saouma has not established that this will occur at Seabrook, he has raised a substantial question as to the likelihood that it may eventually happen.[805] The FSEL study cited by Dr. Saouma refers to bridges and other structures in Japan affected by ASR where reinforcement damage has occurred.[806] The report's authors stated that "it is difficult to comment on the potential for reinforcement fractures in ASR-affected structures found within the United

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[802] Tr. at 650 (Simons).

[803] Tr. at 650–52 (Saouma).

[804] Tr. at 652–53 (Bolourchi).

[805] Ex. INT032, Dr. Saouma Rebuttal Testimony at 19–21.

[806] See Ex. NRC075, Deschenes, et al. at 25–29.

States."[807] They noted that "[t]he results of Miyagawa's study on fracture mechanisms [in Japan] suggest that reinforcement is only subject to brittle failure when significant damage exists at the interior of the bend," but that "American practice dictates the use of large radius bends: two times the bar diameter for the reinforcement used within the Japanese study."[808] But the FSEL study did not rule out the possibility of rebar fractures in the United States, observing that "the lower ductility standards used in the manufacture of American reinforcement may offset the benefits of larger bend radii."[809]

The SGH analyses referred to by Dr. Bayrak show that at present the stress on the rebar is well below the yield strength.[810] This unrebutted evidence is sufficient to justify a reasonable assurance finding regarding the immediate risk of rebar fracture or yielding. At the same time, however, these SGH analyses in no way preclude the significant risk posed by localized rebar fracture or yielding that might reasonably result from continued ASR expansion over the next thirty years of licensed operation. Dr. Bayrak testified that "we can all safely assume, as it was assumed in NextEra programs, that the expansion potential is rather high. Much higher than the limits that are in place."[811] Dr. Saouma has identified a plausible risk that rebar fracture or yielding may occur in the highly stressed areas of seismic Category I structures from the negative impacts of the chemical prestressing effect. As ASR expansion increases, it is reasonable to expect that the negative impacts of chemical prestressing will also increase.

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[807] Id. at 28.

[808] Id. at 29.

[809] Id. For this reason, we are not persuaded that the Seabrook reinforcement steel is not subject to a risk of rebar brittle fracture because it was "designed in accordance with codes that do not permit rebar bending to the extent that would be required for susceptibility to rebar fracture." Ex. INT010, Original LAR at PDF 21 tbl.3. Moreover, this statement in the LAR does not address the risk of rebar yielding.

[810] Ex. INT022, SEM at PDF 91–92 tbl.1.

[811] Tr. at 782 (Bayrak).

We have reviewed NextEra's Structures Monitoring Program, but we have not been able to locate a provision for monitoring the future risk of reinforcement fracture or yielding.[812] NextEra witness Mr. Carley testified that when NextEra removes a concrete core to install an extensometer and exposes the rebar, "we verify that the rebar is solid, pristine, not rusting. No deterioration of the rebar."[813] While this confirms that it is possible to examine installed rebar for signs of deterioration, the examination described by NextEra witness Mr. Carley apparently only occurs in those areas where NextEra happens to uncover the rebar while installing an extensometer. Insofar as future analyses suggest the stress from ASR expansion is approaching the yield strength of the rebar in one or more areas, there is no evidence in the record that NextEra's existing monitoring efforts will ensure that rebar fracture or yielding either does not occur or is detected if it has occurred. The Board therefore concludes that, in order to provide reasonable assurance of adequate protection of public health and safety, it is necessary to add a license condition requiring the development of such a monitoring program contingent on the results of future stress analyses,[814] as follows:

> If stress analyses conducted pursuant to the SEM show that the stress in the rebar from ASR-induced expansion and other loads will exceed the yield strength of the rebar, NextEra must develop a monitoring program sufficient to ensure that rebar failure or yielding does not occur, or is detected if it has already occurred, in the areas at-risk of rebar failure or yielding.

With the addition of this license condition, the Board resolves in NextEra's favor the issues raised by Contention B and incorporated in the reformulated contention.

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[812] See generally Ex. NER007, Seabrook [SMP] Manual Rev. 7 (non-public).

[813] Tr. at 532 (Carley).

[814] See Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 4-1.0 to -2.1 (non-public).

6. Summary of Board Conclusions on Representativeness Issues

The Board holds as to Part VIII.A.3 (Test Specimen Scaling, Reinforcement, and Size) and Part VIII.A.4 (Boundary Conditions) that the LSTP provided data that is sufficiently representative of Seabrook structures to provide reasonable assurance of adequate protection of public health and safety. As to Part VIII.A.2 (Concrete) and Part VIII.A.5 (Effect of Reinforcement (Use of Original Material Properties)), the Board has identified significant uncertainties that preclude a reasonable assurance finding absent the conditions imposed by the Board.[815] With those conditions added, however, the LSTP data is sufficiently representative to satisfy regulatory requirements as to all the representativeness issues raised by C-10.

B. ASR Monitoring Intervals

Under the SMP, NextEra will conduct periodic inspections of ASR-affected structures depending on the severity of ASR expansion as determined via in-situ monitoring.[816] Thus, Seabrook structures with no symptoms of ASR are inspected every five or ten years based on existing SMP requirements.[817] Locations with ASR symptoms and with CCI values below 1.0 mm/m (0.1%) in-plane expansion are monitored every two and a half years.[818] And locations with CCI values of 1.0 mm/m (0.1%) or greater are monitored every six months for in-plane expansion, through-thickness expansion, and volumetric expansion.[819]

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[815] CLI-19-7, 90 NRC at 11 (citing Vt. Yankee, CLI-06-8, 63 NRC at 238).

[816] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 2-1.7, 2-1.9 to -1.15, 3-1.10 (non-public).

[817] Id. at 2-1.7 to -1.8 (non-public).

[818] Ex. INT010, Original LAR at PDF 33 tbl.5.

[819] Id.; Ex. NER001, MPR Testimony at 125.

1. C-10's Prima Facie Case

In Contention H, C-10 presented, and we admitted, a challenge to "the appropriate length of [ASR] monitoring intervals."[820] In his testimony, Dr. Saouma stated that NextEra erroneously assumed that ASR expansion is linear because ASR expands according to a sigmoid curve, which is a plot of expansion versus time that starts linearly and then curves more rapidly upwards before plateauing.[821] The chemical progression of ASR is generally understood to follow a sigmoid curve, which consists of "a dormant period, an active period, and . . . a period where [ASR is] petered out."[822] Dr. Saouma focused on NextEra's failure to establish Seabrook's location on the sigmoid curve.[823] The sigmoid curve for ASR at Seabrook, Dr. Saouma testified, is essential to establishing proper monitoring intervals.[824] Based on Dr. Saouma's testimony, C-10 challenged NextEra's characterization of ASR progression at Seabrook as a "slow reaction," and argued that Seabrook falls within the slower phase of ASR now, but that "the rate of expansion will accelerate at some point."[825] Also, Dr. Saouma asserted that NextEra's method of deriving concrete expansion from the degradation of its elastic modulus is not universally accepted.[826]

Because Dr. Saouma's testimony provides a plausible analysis to support his expert opinion, C-10 has satisfied its burden to present a prima facie case.

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[820] LBP-17-7, 86 NRC at 125; see id. at 121–25.

[821] Ex. INT032, Dr. Saouma Rebuttal Testimony at 12–13, 34 fig.17; Ex. INT027, Dr. Saouma Pre-Filed Testimony at 33 fig.18(b).

[822] Tr. at 387 (Sherman).

[823] Tr. at 413 (Saouma).

[824] Id.; Ex. INT032, Dr. Saouma Rebuttal Testimony at 34.

[825] Ex. INT032, Dr. Saouma Rebuttal Testimony at 12–13.

[826] Tr. at 392–93, 771 (Saouma).

2. NextEra and Staff Responses

NextEra witnesses testified that over the past eight years, Seabrook has shown a relatively steady rate of in-plane expansion, and that this, in turn, indicates that many areas at the facility are in the active portion of the sigmoid curve.[827] In particular, NextEra witness Mr. Simons testified that NextEra measured an in-plane expansion of 0.04 mm/m (0.004%) per year as an average for all Tier 3 structures.[828] NextEra witnesses further testified that the through-thickness expansion rate in the Tier 3 structures was 0.2 mm/m (0.02%) per year,[829] with the most severe structure exhibiting 5.6 mm/m or 0.56% total through-thickness expansion.[830] Still, because NextEra monitors Tier 3 structures every six months,[831] its witnesses testified that even on the steep part of the curve, there are "decades of margin" before Seabrook structures might reach the SMP through-thickness expansion limit determined by the LSTP.[832] Therefore, NextEra witness Mr. Simons testified, a six-month interval is acceptable for monitoring the most ASR-affected areas at Seabrook.[833]

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[827] Tr. at 399–400 (Simons). NextEra testified that, based on the qualitative descriptions in Dr. Saouma's sigmoid curve, see Ex. INT027, Dr. Saouma Pre-Filed Testimony at 33 fig.18(b), Seabrook is in the active phase/accelerating stage (i.e., stages iii, iv, and v). Tr. at 421–22 (Sherman).

[828] Tr. at 415–16 (Simons).

[829] Tr. at 685–86 (Simons), 695 (Bayrak). NextEra witness Mr. Carley testified that NextEra is seeing a rate, "over a six-month period, of .02[%] increasing." We find this testimony somewhat unclear but interpret it to mean 0.2 mm/m (0.02%) through-thickness expansion per year, consistent with other testimony. Tr. at 1136 (Carley)

[830] Ex. NER007 Ex. NER007, Seabrook [SMP] Manual Rev. 7 at B-14 tbl.2 (non-public); Tr. at 421 (Simons), 510 (Simons), 559 (Bagley), 1136 (Carley).

[831] Ex. INT010, Original LAR at PDF 33 tbl.5.

[832] Tr. at 415–16 (Simons), 713–14 (Collins); see Tr. at 695–96 (Bayrak) (stating that "in the worst case . . . there is no reason to expect" that you will be "over the limit" within the next six-month inspection); see also Tr. at 1126–27 (Lehman); Tr. at 691–92 (Buford) (stating that six-month monitoring frequency is a conservative option).

[833] Tr. at 415–16 (Simons) ("So clearly a six-month interval is completely acceptable for monitoring something that is going that slow.").

NextEra determined that the through-thickness acceptance limit may be reached within the licensed operating timeframe of Seabrook.[834] NextEra witnesses testified that, based on an expansion rate from the ISE document,[835] (which is also the Tier 3 through-thickness expansion rate at Seabrook),[836] a steady expansion rate of 0.2 mm/m (0.02%) per year will push Seabrook over the through-thickness expansion limit ([redacted] mm/m or [redacted]%) in [redacted].[837] NextEra witnesses stated that the Staff-imposed license condition to perform periodic expansion assessments "includes an activity to evaluate the rate of ASR progression based on the observed expansion data and the margins to the acceptance criteria."[838] They further testified that "[i]f evidence suggests that the monitoring intervals (or any other aspect of the SMP) at Seabrook are insufficient, the plant will evaluate the need for potential changes."[839]

In addition, under the Staff's license condition, NextEra is required to conduct a Corroboration Study to determine whether expansion as determined by the modulus correlation matches actual expansion at the plant.[840] If the data do not match, NextEra is required to establish pre-instrument through-thickness, reassess total through-thickness (and volumetric) expansion against the acceptance criteria from the LSTP, and "determine whether the structures [a]re operable and whether their licensing basis need[s] to be changed to address it."[841]

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[834] Tr. at 416 (Simons).

[835] Ex. NER012, ISE Structural Effects of [ASR] at 32 (non-public).

[836] See supra note 829 and accompanying text.

[837] See Ex. NER003, MPR Testimony, Proprietary Appendix at 2 tbl.3 n.3 (non-public).

[838] Ex. NER001, MPR Testimony at 129; see Ex. INT024, Final SE at PDF 67–69.

[839] Ex. NER001, MPR Testimony at 129.

[840] Id. at 62, 120–21.

[841] Tr. at 742 (Buford); see infra Part VIII.D.

With regard to the sigmoid curve, as indicated earlier, NextEra witness Mr. Sherman testified that it consists of "a dormant period, an active period, and . . . a period where [ASR has] petered out."[842] NextEra witnesses further testified that, according to modulus testing conducted by NextEra, Seabrook is in the active phase, which is "the steep part of the curve" beyond the inflection point.[843] In addition, NextEra witness Mr. Simons stated NextEra did not assume ASR progressed linearly, but instead that ASR in-plane expansion data from Seabrook has exhibited a relatively linear trend.[844]

Staff witnesses testified that through-thickness expansion is measured starting at the relatively small in-plane expansion level of 1.0 mm/m (0.1%).[845] According to Staff witnesses, since it is measured every six months, even the fastest possible expansion could not exceed the expansion limits before the end of the next monitoring interval.[846] Further, Staff witness Dr. Thomas noted that "[t]here has been no case history where we [have] seen that ASR was the primary cause of the structural failure of collapse" and therefore "the risk related to ASR is relatively low, provided it's monitored and managed."[847] From this, Staff witness Mr. Lehman testified that where Seabrook falls on the sigmoid curve "had no bearing on [the Staff's] reasonable assurance determination."[848] NextEra witnesses testified, however, that "the only need for understanding [the] rate of expansion at Seabrook is validation that the monitoring frequency is sufficient, and NextEra is using in-situ monitoring for this purpose."[849]

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[842] Tr. at 387 (Sherman).

[843] Tr. at 389–90 (Sherman); Tr. at 399–400, 415 (Simons).

[844] Tr. at 399 (Simons).

[845] Ex. NRC001-R, Staff Testimony at 45.

[846] Tr. at 420 (Buford), 1122–24 (Buford).

[847] Tr. at 1115 (Thomas).

[848] Tr. at 1122–23 (Lehman).

[849] Ex. NER001, MPR Testimony at 152.

3. Findings of Fact and Board Analysis

Based on the preponderance of the evidence in the record before us regarding the ASR monitoring interval for Tier 3 areas, the Board finds that the ASR monitoring intervals under the SMP fail to provide reasonable assurance in accordance with 10 C.F.R. §§ 50.40(a) and 50.57(a) that operation of Seabrook Unit 1 will not endanger the health and safety of the public. Specifically, NextEra has not shown by a preponderance of the evidence that the current SMP can effectively account for an increase in the rate of ASR expansion, especially when NextEra's own data indicates the SMP through-thickness expansion limit may be reached in [redacted].[850] We find action must be taken by NextEra well before the through-thickness expansion limit is reached. Since the license renewal authorizes operation until March 15, 2050, the Board finds that NextEra must establish a tangible mechanism that will detect an increased expansion rate and timely implement more frequent monitoring intervals, if necessary, because of an increased expansion rate.

By NextEra's own admission, the through-thickness expansion acceptance limit will be exceeded in [redacted], with [redacted] additional years of licensed operation.[851] By our calculations,[852] based on the most severe through-thickness cracking in the Tier 3 areas (5.6 mm/m or 0.56%) and assuming a steady expansion rate of 0.2 mm/m or 0.02% as observed at Seabrook Unit 1,[853] in 2050 the maximum through-thickness expansion will be 12.4 mm/m (1.24%). This is [redacted] mm/m ([redacted]%) above the expansion limit. In fact, by our calculation, the [redacted] mm/m ([redacted]%)

[850] See Ex. NER003, MPR Testimony, Proprietary Appendix at 2 tbl.3 n.3 (non-public).

[851] Id. (non-public).

[852] We assumed that the most severe cracking in Tier 3 (5.6 mm/m or 0.56%) areas was measured in 2016, when through-thickness expansion monitoring began, see Ex. NER001, MPR Testimony at 126, and that there would be 0.2 mm/m (0.02%) of expansion per year throughout the remaining operating period (i.e., 2016 to 2050).

[853] NextEra witnesses further testified that the through-thickness expansion rate in the Tier 3 structures was 0.2 mm/m (0.02%) per year. Tr. at 685–86 (Simons), 695 (Bayrak).

through-thickness expansion acceptance limit may be reached in [redacted], with [redacted] years of licensed operation remaining.[854]

If in fact the expansion rate were to increase 20% to 0.24 mm/m (0.024%) per year, then the through-thickness expansion acceptance limit would be reached by [redacted]. However, even without considering that the expansion rate may increase, a steady expansion rate will put NextEra beyond the acceptance limit within its licensed operating timeframe. We also note that the ISE document states that ASR does not expand uniformly within a given structure, adding another variable to future ASR expansion.[855] The Board finds that there is no conclusive evidence as to whether the through-thickness expansion rate will or will not accelerate during the next thirty years. The question turns in large part on where Seabrook's concrete is on the sigmoid curve that represents the typical path of ASR expansion.[856] While NextEra witnesses testified that Seabrook's concrete is already on the active/steep part of the sigmoid curve,[857] Dr. Saouma testified that "Seabrook is most likely in the very early slower phase, but the rate of expansion will accelerate at some point."[858] Through-thickness expansion monitoring only began in 2016,[859] and the Board lacks data sufficient to demonstrate that NextEra knows where it is on the sigmoid curve. NextEra witness Mr. Sherman testified that Seabrook concrete is on the active part of the curve based on elastic modulus testing and petrography.[860] Dr. Saouma responded, however, that NextEra's method is "not yet mature enough to be able to perform a

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[854] We used the following equation: ([redacted] x 0.2 mm/m) + 5.6 mm/m = [redacted] m/m. [redacted] years from 2016 is [redacted].

[855] Ex. NER012, ISE Structural Effects of [ASR] at 31 (non-public).

[856] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32 fig.18.

[857] Tr. at 399 (Simons).

[858] Ex. INT032, Dr. Saouma Rebuttal Testimony at 13.

[859] Ex. NER001, MPR Testimony at 126.

[860] Tr. at 387–90 (Sherman).

quantifiable assessment of expansion based on . . . the change of elastic [modulus]."[861] The Board therefore finds that the position of Seabrook concrete on the sigmoid curve is uncertain.

The Board further finds, given that the expansion rate may increase as Dr. Saouma claims, that there is a significant risk that the current six-month monitoring frequency for Tier 3 areas may prove inadequate over the thirty years of licensed operation. The Staff testified that, in terms of its regulatory review, "there really wasn't a requirement to identify where the plant is on the sigmoid curve as long as the inspection frequencies were frequent enough to capture expansion prior to hitting the limits."[862] Staff witnesses noted that the expansion rate could increase 1,000% in six months in the location with the highest through-thickness expansion (5.6 mm/m or 0.56%) and still be well below the expansion limits.[863] That is true at present, but reasonable assurance requires that the six-month monitoring interval provide adequate protection for the remaining thirty-year period of licensed operation. As explained above, the [redacted] mm/m ([redacted]%) through-thickness expansion acceptance limit will likely be reached during the thirty-year period of licensed operation, at least in the most degraded areas. As the total level of expansion in a degraded area approaches the expansion limit, a smaller increase in the expansion rate will be sufficient to push the total expansion over the limit before the next inspection. Thus, the risk will increase that the current six-month monitoring frequency for Tier 3 areas will not comply with the Staff's requirement that "testing frequencies are short enough that there isn't the potential for structural loss of function in between the inspection intervals."[864] Moreover, the sigmoid curve indicates that the expansion rate may increase over time, as Dr.

[861] Tr. at 393 (Saouma).

[862] Tr. at 420 (Buford).

[863] Ex. NRC091, Staff Response to Ex. INT051-R at 5.

[864] Tr. at 1122 (Buford).

Saouma testified, making it more likely that the six-month monitoring interval will not be frequent enough to capture expansion prior to reaching the limit.

The Board disagrees with NextEra and the Staff that the six-month interval for Tier 3 areas is the most stringent identified in the public literature. NextEra witnesses testified that the six-month monitoring interval reflects the most frequent interval recommended by the FHWA.[865] The Staff emphasized that six months is the most frequent monitoring interval it is aware of.[866] However, application of the ISE document, which NextEra and the Staff have cited as authoritative on other issues,[867] would likely have resulted in more frequent monitoring for Seabrook. The ISE document classifies structures in different categories based on an expansion index, the risk of failure, the site environment, and "[r]einforcement detailing class."[868] The detailed inspections and monitoring of cracks in ASR-affected structures proceeds according to the degradation categories:

(i) Category A (Very Severe) – Monitored every (1) month

(ii) Category B (Severe) – Monitored every two (2) months

(iii) Category C (Moderate) – Monitored every four (4) months

(iv) Category D (Mild) – Monitored every twelve (12) months[869]

[865] Ex. NER001, MPR Testimony at 128.

[866] Tr. at 420 (Buford) ("So six months is about the most frequent that in my knowledge for any aging mechanism, ASR included, that would -- I don't know of any program that would look at something more frequently than that.").

[867] Ex. NER001, MPR Testimony at 16, 39, 41, 45, 54, 82, 89, 122, 128, 137; Ex. NRC091, Staff Response to Ex. INT051-R at 4–5; NRC Staff's Supp. Proposed Findings of Fact and Conclusions of Law at 3 n.16, 7 n.40.

[868] Ex. NER012, ISE Structural Effects of [ASR] at 20 tbl.5 (non-public).

[869] Id. at 30–31, 31 tbl.7 (non-public).

Unless the Seabrook structures with Tier 3 expansion would be classified in Category D, which seems unlikely,[870] the initial monitoring interval for Seabrook seismic Category I structures would have been less than six months.[871]

The Commission indicated that the Board should consider "whether the inspection intervals are sufficiently protective of public health and safety" and "whether the maintenance rule [10 C.F.R. § 50.65(a)(1)] affects this inquiry."[872] The maintenance rule directs licensees to "monitor the performance or condition of structures, systems, or components, against licensee-established goals, in a manner sufficient to provide reasonable assurance that these structures, systems, and components . . . are capable of fulfilling their intended functions."[873] Having found that the six-month inspection interval may not be sufficiently protective for the remaining period of licensed operation, we consider whether NextEra's guidance for implementing the maintenance rule alters that conclusion.

NextEra's SMP states that it "provides guidance for the conduct of the structural condition monitoring program to meet the requirements of [the maintenance rule]."[874] The SMP, however, lacks any requirement that NextEra management timely evaluate the need for more frequent monitoring intervals if it detects a significant increase in the ASR expansion rate or otherwise detects "the potential for structural loss of function in between the inspection

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[870] A Category D structure must either be located in a dry environment or the consequence of structural failure must be slight. Id. at 20 tbl.5 (non-public). It is also hard to say Seabrook structures would be classified in Category A (Very Severe) or B (Severe) because those categories involve remedial work and/or load restrictions. Id. at 30 (non-public).

[871] The ISE document permits inspection intervals for severity ratings C and D to be relaxed from 4 and 12 months, respectively, once trends for a structure have been established and moisture conditions are stable. Id. Addendum at 3 of 5 (non-public).

[872] CLI-18-4, 87 NRC at 110 n.152.

[873] 10 C.F.R. § 50.65(a)(1).

[874] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 1-1.1 (citing 10 C.F.R. § 50.65) (non-public).

intervals."[875] The SMP states that "Follow-Up and Interim inspections may be performed in addition to the required 6-month or 30-month frequency inspections," but any such action is entirely "at the discretion of the engineer."[876] The SMP provides no guidance as to how the discretion is to be exercised.

In the absence of evidence to the contrary, NRC does not presume that a licensee will violate agency regulations whenever the opportunity arises.[877] The Board makes no such presumption here. The problem with the SMP is the lack of any specific directive as to when additional inspections must be performed. This creates a reasonable possibility of a violation of the maintenance rule's requirement that NextEra monitor the condition of Seabrook seismic Category I structures so as to provide reasonable assurance that those structures remain capable of fulfilling their intended functions for the period of licensed operation.[878]

Apart from the SMP, NextEra witnesses testified that the Staff's license condition to perform periodic expansion assessments will require evaluation of the monitoring intervals.[879] The condition requires that if NextEra's projections of future expansion "indicate that the limits may be exceeded prior to the next periodic check, NextEra should further investigate the location(s) in question or develop contingency plans for extending the expansion limit (e.g., supplemental testing)."[880] Thus, NextEra may avoid investigating the location of concern by developing plans for supplemental testing to increase the expansion limits, presumably by a

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[875] Tr. at 1122 (Buford).

[876] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 3-1.10 (non-public).

[877] See Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), CLI-01-9, 53 NRC 232, 235 (2001). The Board makes no such presumption. The issue is the vagueness of the programmatic actions to be taken. The result could be an inadvertent violation of the maintenance rule.

[878] 10 C.F.R. § 50.65(a)(1).

[879] Ex. NER001, MPR Testimony at 129.

[880] Ex. INT019-R, MPR-4273 at B-2 to -3 (emphasis added); see Ex. INT024, Final SE at PDF 68–69.

testing program similar to the LSTP that could take years to create and implement. NextEra witnesses also testified that the plant will evaluate the need for potential changes "[i]f evidence suggests that the monitoring intervals . . . at Seabrook are insufficient,"[881] but they failed to identify any provision of the SMP or other NextEra document requiring such action.

Thus, the Board finds the SMP and the Staff's license condition inadequate to fulfill the maintenance rule's directive that a licensee monitor the condition of its structures "in a manner sufficient to provide reasonable assurance that these structures . . . are capable of fulfilling their intended functions."[882] To remedy this deficiency, the Board imposes the following license condition:

> If the ASR expansion rate in any area of a Seabrook seismic Category I structure significantly exceeds 0.2 mm/m (0.02%) through-thickness expansion per year, NextEra's Management will perform an engineering evaluation focused on the continued suitability of the six-month monitoring interval for Tier 3 areas. If the engineering evaluation concludes that more frequent monitoring is necessary, it shall be implemented under the SMP.[883]

As stated above, NextEra admitted that the SMP through-thickness expansion acceptance limit may be exceeded in [redacted], even though there will be five additional years of licensed Seabrook operations.[884] This in itself requires NextEra to ensure the adequacy of its monitoring frequencies so that it will capture any deleterious increase in concrete expansion rates. Therefore, to provide reasonable assurance of adequate protection of public health and safety, the Board imposes the above license condition in order to ensure adequate ASR monitoring frequencies at Seabrook Unit 1.

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[881] Ex. NER001, MPR Testimony at 129.

[882] 10 C.F.R. § 50.65(a)(1).

[883] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 3-1.10 (non-public).

[884] Id. (non-public).

C. Accelerated Expansion Tests and Alternative Methodologies

C-10 argued NextEra should have performed an accelerated expansion test.[885] An accelerated expansion test is a procedure that measures the ultimate potential for ASR expansion of a concrete sample.[886]

1. Motion in Limine

NextEra argued Dr. Saouma's testimony on alternative methodologies, such as conducting accelerated expansion tests[887] and using probabilistic based analyses,[888] should be excluded from the evidentiary record.[889] NextEra asserted that we denied admission of Contention G for attempting to prescribe a specific methodology, rather than address the adequacy of the chosen methodologies,[890] and therefore Dr. Saouma's attempts to prescribe specific methodologies are irrelevant and immaterial.[891] NextEra argued "the mere presentation of an alternative method of regulatory compliance is irrelevant to the question . . . whether the method presented by the applicant satisfies regulatory requirements."[892] Therefore, NextEra seeks to exclude Dr. Saouma's testimony insofar as it discusses alternative methodologies,

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[885] C-10 Rebuttal SOP at 4; Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32–33.

[886] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32 (ASR "can be accelerated by storing [Seabrook concrete] cores at temperatures ranging from 38 to 60 deg C. Small 'disks' are glued on the cores, the cores are then placed in a container, and the container in a so called reactor which is heated to the right temperature, ... The cores are periodically extracted, and the elongation is measured with a so-called [Differential Electrical Mobility Classifier] instrument between the disks").

[887] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony §§ C.2.1, C.5, C.6, C.8, C.11 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony §§ C.2.1, C.5, C.6, C.8, C.11; see Tr. at 378–79 (Saouma).

[888] Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.3.4.1.1.

[889] NextEra MIL 2 at 10–12.

[890] LBP-17-7, 86 NRC at 133–35.

[891] NextEra MIL 2 at 10–12.

[892] Id. at 10 (emphasis omitted).

including general references to a probabilistic based method, accelerated expansion tests, "detailed petrographic stud[ies],"[893] ultrasonic pulse echo, ultrasonic pulse velocity,[894] impact-echo,[895] acoustic emission,[896] RH/capacitance probe, wood stick, microwave technique: GPR, microwave technique: TDR, and microwave technique: open-ended coaxial probe.[897]

The Staff similarly argued that consideration of alternative techniques is beyond the scope of its review of NextEra's license amendment request because the Staff's responsibility is to ensure that the applicant "is guided by the considerations that govern the issuance of the initial licenses."[898] Thus, the Staff asserted, any argument requesting an alternative approach is outside the scope of the proceeding.[899]

In opposing NextEra's Motion in Limine, C-10 claimed that Dr. Saouma's arguments concerning alternative compliance methodologies are properly before the Board.[900] C-10 maintained that Dr. Saouma is not stating that there are better alternatives, but rather that his testimony demonstrates the inadequacy of the methods used by NextEra by comparing it to more effective methods.[901]

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[893] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 5, 20, 31, 32, 35–36; id. at 31 (advocating for the use of petrographic damage rating index (DRI)); see Ex. INT040, Assessment of ASR Using DRI at 90 (non-public).

[894] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 35–36.

[895] Id.

[896] Id.; Tr. at 1150–51 (Saouma).

[897] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 35–36.

[898] See NRC Staff SOP at 47 (citing 10 C.F.R. § 50.92(a)). The Staff further underscored that it is not their responsibility to "determine whether the request could be achieved in some other, arguably better, manner[.]" Id.

[899] Id. at 47–48.

[900] C-10 Opp. to MIL 2 at 6–9.

[901] Id. at 8–9.

We hold that the need to conduct accelerated expansion tests is rooted in a lack of representativeness and invokes the issue regarding the adequacy of monitoring intervals that we found admissible in Contention H. The testimony is therefore material and relevant to the reformulated contention. However, regarding a probabilistic-based method and Dr. Saouma's list of alternative methodologies to using CCI,[902] since we have found the use of the CCI acceptable subject to our license condition,[903] we need not consider the relevancy or materiality of the listed alternatives to CCI.

Dr. Saouma suggested three main reasons for conducting accelerated expansion tests: to determine (1) a technical basis for the inspection intervals; (2) Seabrook's location on the sigmoid curve; and (3) the ultimate potential for ASR expansion.[904] Both the monitoring intervals and the overall issue of representativeness are implicated in C-10's assertions that an accelerated expansion test should be conducted. With regard to representativeness, Dr. Saouma testified that "[a]ccelerated expansion tests would have allowed a comparison to determine the extent to which the Seabrook concrete and the [LSTP] concrete differed."[905] Thus, one purpose of accelerated expansion tests is to confirm that the LSTP concrete is, or is not, representative of Seabrook. Dr. Saouma also stated that accelerated expansion tests can provide information to help determine where Seabrook is on the sigmoid curve.[906] We find that Seabrook's location on the sigmoid curve would inform the adequacy of monitoring intervals, a topic within the scope of this proceeding. Contention H, which we found "admissible but limited to the appropriate length of monitoring intervals[,]" is implicated in C-10's testimony concerning

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[902] See supra notes 893–897 and accompanying text.

[903] See supra Part VIII.A.2.d.

[904] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32–33; Tr. at 386, 415 (Saouma).

[905] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 10.

[906] Id. at 32–33.

accelerated expansion tests.[907] Therefore, contrary to NextEra's argument, C-10 did not assert the need for an accelerated expansion test as a "mere presentation of an alternative method of regulatory compliance"[908] but rather to probe the adequacy of two components of the reformulated contention with its testimony.

A key inquiry of this proceeding is whether the proposed monitoring intervals are adequate to capture ASR expansion at Seabrook, and that adequacy is based largely on whether the LSTP is sufficiently representative of Seabrook.[909] As such, although NextEra may have indicated a tenuous relationship between accelerated expansion tests and inadmissible Contention G, there are two connections between accelerated expansion tests and the reformulated contention—representativeness and the adequacy of ASR monitoring intervals. Therefore, we hold the testimony surrounding accelerated expansion tests is both material and relevant to resolving the reformulated contention, and we deny NextEra's Motion in Limine regarding accelerated expansion tests.

We also find no merit in NextEra's argument that testimony concerning accelerated expansion tests should be excluded on the same grounds that we excluded Contention G.[910] Contrary to NextEra's assertions, we did not reject Contention G merely because it involved an alternative methodology, but because it would have required testing to the point of failure, or the "tipping point," which would have provided less conservative expansion limits than those in the LAR.[911] The accelerated expansion tests proposed by Dr. Saouma, however, would not

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[907] LBP-17-7, 86 NRC at 125.

[908] NextEra MIL 2 at 10.

[909] LBP-17-7, 86 NRC at 122–23.

[910] Id. at 134–35.

[911] See id. at 135 (holding that Contention G failed to raise a material issue because "the current ASR levels at Seabrook and the LAR acceptance criteria are bounded by the test program, such that the tipping point would not be reached before the acceptance criteria are exceeded"). As

necessarily propose less conservative monitoring intervals than those in the LAR; they might result in more frequent monitoring intervals than proposed by NextEra. This is one instance in which it is not only appropriate, but also necessary to consider alternative tests proposed by C-10 to determine whether the LAR provides adequate protection of public health and safety.[912] Thus, previously declining to admit Contention G in no way renders out of scope C-10's proffered testimony on accelerated expansion tests.

Concerning petrographic damage rating index (DRI), Dr. Saouma stated that NextEra "prematurely ruled out the applicability of petrographic DRI" and that petrographic analysis should be conducted in conjunction with CCI.[913] In addition, Dr. Saouma proffered several alternatives to CCI, as noted above.[914] NextEra argued that these are alternative compliance methods that should be excluded from the record.[915] We need not address here whether these alternatives to CCI should be excluded, because, as elaborated above, we find that using CCI as a monitoring technique is sufficient when analyzed with the additional assurances provided by our license condition.[916]

Turning to the probabilistic-based methods suggested by Dr. Saouma,[917] we grant NextEra's Motion in Limine. Dr. Saouma advocated for the use of probabilistic-based methods,

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the Staff argued, "the LAR is structured such that the limits on the Seabrook concrete are more conservative than the 'tipping point' of the concrete[.]" Id. at 134.

[912] See Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), LBP-88-13, 27 NRC 509, 548–49, aff'd in part, vacated in part, and remanded, ALAB-905, 28 NRC 515 (1988) (reviewing alternative compliance methods to determine reasonable assurance); see also Palisades, CLI-15-22, 82 NRC at 317–18 (noting alternative methods can demonstrate reasonable assurance).

[913] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 20, 31.

[914] See supra notes 893–897 and accompanying text.

[915] NextEra MIL 2 at 10–12.

[916] See supra Part VIII.A.2.d.

[917] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 29–31. Dr. Saouma stated "[p]robabilistic risk (or safety) assessment (PRA) consists of an analysis of the operations of a particular nuclear power plant (NPP), which focuses on the failures or faults that can occur to

in lieu of NextEra's code-based approach.[918] Although such methods could be material under GDC 1, which permits supplementation of general codes and standards,[919] we need not address them here for two reasons. First, they were not addressed in C-10's Petition. Second, unlike accelerated expansion tests, they are unrelated to any of the bases of the reformulated contention, and therefore do not fall within the scope of this proceeding.

We also exclude all of C-10's proffered testimony referring to the methodologies used at other structures and power plants.[920] Such testimony is unrelated to the representativeness of the LSTP, and unrelated to Seabrook in general. Therefore, with regard to testimony comparing ASR monitoring methods used at Seabrook to other structures and power plants, we grant NextEra's Motion in Limine and decline to address such testimony.[921]

2. C-10's Prima Facie Case

Dr. Saouma testified that an accelerated expansion test is an "easy test"[922] that NextEra should have performed to gauge where Seabrook structures are on the sigmoid curve.[923] Such a test creates a plot of ASR expansion versus time for the concrete test sample.[924] Dr. Saouma stated that:

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components, systems or structures, and that can lead to damage and ultimately to the release of radioactive material, especially the fission products and actinides within the reactor fuel." Id. at 30.

[918] See generally id.; Ex. INT032, Dr. Saouma Rebuttal Testimony.

[919] "Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function." 10 C.F.R. pt. 50, app. A § I (emphasis added).

[920] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 34; Ex. INT032, Dr. Saouma Rebuttal Testimony at 4–6.

[921] NextEra MIL 2 at 10–12.

[922] Tr. at 400 (Saouma).

[923] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32–33.

[924] Id. at 32.

> It is . . . problematic that FSEL failed to perform the accelerated expansion tests of Seabrook and [LSTP] concrete cores. Accelerated expansion tests would have allowed a comparison to determine the extent to which the Seabrook concrete and the [LSTP] concrete differed. As a result of FSEL's failure to use identical concrete in [the LSTP], and its failure to conduct accelerated expansion tests, it is impossible to predict with any confidence the maximum expansion at Seabrook. Essentially, that figure is completely unknown. This is a significant problem that could have been easily avoided.[925]

Additionally, Dr. Saouma testified that without conducting an accelerated expansion test, NextEra cannot determine "the maximum likely degree of expansion."[926] Dr. Saouma stated that accelerated expansion tests are "[t]he only way" to "assess the potential for future expansion."[927] In addition to accounting for maximum ASR expansion, Dr. Saouma testified that accelerated expansion tests account for the specific kinetic reactions of ASR.[928] Dr. Saouma asserted that the FHWA Report supports the assertion that accelerated expansion testing can determine the ultimate expansion of ASR.[929] Dr. Saouma also testified that an accelerated expansion test could provide a technical basis for the inspection intervals in the LAR, in addition to determining the ultimate ASR expansion.[930]

In addition to asserting NextEra should conduct acceleration expansion tests, C-10 advocated developing calibrated numerical models.[931] Dr. Saouma testified that "periodic

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[925] Id. at 10.

[926] Id. at 11.

[927] Tr. at 505–06 (Saouma); Tr. at 772 (Saouma).

[928] Ex. INT032, Dr. Saouma Rebuttal Testimony at 13 ("Kinetics can be assessed through accelerated expansion tests as described in EPRI Report 3002013192, Exhibit NER01[7]." (citing Ex. NER017, EPRI Report 3002013192, "Evaluation of Laboratory Tests to Detect Up-to-Date Expansion and Remaining Expansion in Concrete Structures Affected by Alkali-Silica Reaction" (Oct. 15, 2018) at 2-1 [hereinafter Ex. NER017, EPRI Report] (non-public))).

[929] Tr. at 325–26 (Saouma); Ex. NER013, FHWA Report at 26–27.

[930] Tr. at 385–86 (Saouma).

[931] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 32–36; Ex. INT032, Dr. Saouma Rebuttal Testimony at 8–10; Tr. at 306, 310–11, 839–40 (Saouma).

damage rating index (DRI) measurements, detailed petrographic studies, and modern computational methods" should be developed since they are "demonstrably effective[.]"[932]

Dr. Saouma's testimony provides a plausible analysis to support his opinion. C-10 has therefore satisfied its burden to present a prima facie case.

3. NextEra and Staff Responses

NextEra witnesses testified that NextEra did not need to determine ultimate expansion because its methods focused on determining accurate monitoring frequencies and acceptance limits.[933] NextEra witness Dr. Bolourchi indicated that monitoring structures based on threshold factors does not require the evaluation of the rate of ASR growth because threshold factors are insensitive to the rate of ASR growth.[934]

NextEra witnesses testified that accelerated expansion tests would not provide any useful data for its chosen monitoring programs. For example, NextEra witness Mr. Sherman testified that using an artificially high temperature and 100% relative humidity would result in data that bear no relationship to the parameters of the SMP.[935] Additionally, NextEra witness Mr. Bagley testified that, depending on the method used, accelerated expansion tests are not representative "of the actual condition of the aggregate . . . [and such tests are conducted]

[932] Ex. INT032, Dr. Saouma Rebuttal Testimony at 9.

[933] Ex. NER001, MPR Testimony at 129, 137–38; id. at 152 ("[T]he only need for understanding [the] rate of expansion at Seabrook is validation that the monitoring frequency is sufficient, and NextEra is using in-situ monitoring for this purpose.").

[934] See Tr. at 937–38 (Bolourchi).

[935] Tr. at 377–78 (Sherman) ("One of the accelerated tests that you do exposes it to large amounts of alkali in high temperature. The idea behind that is it says how much might this stone react if everything else is provided to it. We know that's not the case. There's not an infinite source of alkali at the plant. All that's there is what was built into it. The other test says if I keep it at a high temperature and 100[%] relative humidity, water dripping off of it, where it might go somewhere down the road. We don't have high temperatures and 100[%] humidity. So I have a data point, but I don't know what it means.").

outside of [their] structural context."[936] Therefore, Mr. Bagley concluded, the accelerated expansion tests that C-10 suggested would not be "directly relatable back to what's in the plant."[937] Further, unconfined concrete would be used for an accelerated expansion test, which is not representative of conditions at Seabrook.[938] In arguing the non-representative nature of accelerated expansion tests, NextEra witness Dr. Bayrak emphasized that the ultimate expansion data in such a test may be several orders of magnitude greater than actual conditions.[939] Dr. Bayrak further stressed that the data "serves absolutely no purpose"[940] and merely provides a "worst case scenario."[941]

NextEra witness Mr. Carley asserted that an accelerated expansion test is not "easy," as suggested by Dr. Saouma,[942] but rather "a very tedious, expensive, [and] difficult process" that could damage the structural rebar.[943] For example, an accelerated expansion test would require NextEra to extract 4-inch cores, which is roughly the spacing between the rebar in Seabrook structures.[944] NextEra has already extracted in-situ cores to determine through-thickness expansion to date, even though it found the extraction process to be "a time consuming, very difficult process."[945] NextEra is obligated, as part of the license condition

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[936] Tr. at 379–80 (Bagley).

[937] Tr. at 380 (Bagley).

[938] Tr. at 380–81 (Sherman).

[939] Tr. at 781–82 (Bayrak).

[940] Tr. at 782 (Bayrak).

[941] Tr. at 781 (Bayrak).

[942] Tr. at 400 (Saouma).

[943] Tr. at 381 (Carley).

[944] Id.

[945] Id.

Corroboration Study[946] to extract cores at set intervals to ensure the LSTP results remain valid as model for assessing ASR expansion at Seabrook.[947]

NextEra witnesses further testified that NextEra conducts trending analyses and extrapolates actual data from the plant to determine whether Seabrook structures will remain within the expansion limits, and as a consequence, NextEra does not need to identify ultimate ASR expansion in an artificial setting conducive to ASR expansion.[948] NextEra witness Mr. Carley testified that NextEra determined through-thickness expansion to date by extracting over 200 in-situ cores and then extrapolating the data to assess long-term expansion limits.[949]

C-10 disputed NextEra's claim that once cores are removed from the structures, they are no longer representative. Dr. Saouma testified that NextEra tested the 200 extracted cores for compressive strength and elastic modulus, notwithstanding representativeness issues.[950] Thus, Dr. Saouma stated that NextEra's position is hypocritical because NextEra conducted other analyses on the extracted cores and deemed the resulting data representative.[951] From this, Dr. Saouma stated that if NextEra used the cores to gather pertinent data for compressive strength and elastic modulus, it can also use the same cores in an accelerated expansion test.[952]

According to NextEra witness Mr. Carley, however, the process of determining the elastic modulus destroys the cores which renders them unavailable for use in accelerated

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[946] Ex. INT024, Final SE at PDF 67–69; Ex. NER001, MPR Testimony at 61–62.

[947] Tr. at 381–82 (Carley) ("We have committed to do additional cores for [the] [C]orroboration [S]tudy in the future. But just to take cores for doing an accelerated test, and as you heard, that probably is not going to provide value to the method we have chosen was a route that we have chosen not to take.").

[948] Tr. at 380–81 (Sherman); Ex. NER001, MPR Testimony at 129.

[949] Tr. at 381 (Carley).

[950] Tr. at 384–85 (Saouma).

[951] Id.

[952] Id.

expansion tests.[953] With the original cores destroyed, further core sampling would be required, resulting in additional destructive testing to Seabrook's structures.[954]

The Staff agreed with NextEra that an accelerated expansion test is not required, arguing that C-10 failed to establish why understanding ultimate ASR expansion is a safety concern.[955] Staff witnesses also testified that NextEra's approach "identified reasonable and justifiable structure-specific expansion limits[] which account for potential future expansion[.]"[956] Staff witnesses stated that "[k]nowing the ultimate expansion is not relevant to the approach chosen by NextEra because the ultimate expansion is irrelevant as long as the structures are monitored and remain below the limits."[957]

NextEra conducted residual reactivity testing to determine whether Seabrook is prone to future ASR expansion or whether the reaction has been exhausted. In 2012, NextEra performed residual reactivity testing per ASTM C 1260, which is a method intended to test an aggregate source for potential reactivity before new construction.[958] NextEra obtained the aggregate from cores removed from existing Seabrook structures.[959] Thereafter, NextEra used the aggregate to:

> [F]abricate a mortar bar and submerged [it] in a hot sodium hydroxide solution to accelerate expansion. Per ASTM C 1260, the aggregate is determined to be reactive if an expansion of greater than [1.0 mm/m (0.1%)] is observed. The test results showed an expansion of over [7.0 mm/m (0.7%)] with no sign of plateauing after 103 days, indicating that Seabrook is susceptible to future expansion. Accordingly, NextEra conservatively assume[d] that ASR could

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[953] Tr. at 382 (Carley).

[954] Tr. at 381–82 (Carley).

[955] Ex. NRC001-R, Staff Testimony at 71.

[956] Id.

[957] Id. at 71–72.

[958] Ex. NER001, MPR Testimony at 137–38.

[959] Id.

> continue through the remainder of plant life and [that there is no] maximum bound on potential expansion.[960]

NextEra also calculated that it expects to exceed the through-thickness expansion limit in the most severe area by [redacted].[961] NextEra concluded:

> The quantitative results of the [ASTM C 1260] test were not useful because the composition and structural context of the mortar bar [is] vastly different than [that at] the plant. No further residual reactivity testing was performed, because there was (and still is) no further application for the results, given the assumption of unbounded potential ASR progression.[962]

NextEra witnesses also addressed the question why NextEra did not perform reactivity testing on the LSTP specimens, indicating:

> With respect to the LSTP specimens, reactivity testing was never performed because the information from this testing would not have been useful. The concrete mixture design was known, and was intentionally susceptible to ASR, so there was no need to confirm reactivity . . . . Even if the maximum possible expansion of the LSTP test specimens were known, it would not have affected interpretation of the results, which related structural performance to the measured expansion (regardless of the potential future expansion).[963]

Responding to NextEra's argument, Dr. Saouma stated that an accelerated expansion test could provide a technical basis for the inspection intervals in the LAR, in addition to determining the ultimate ASR expansion.[964] Further, he reiterated that NextEra must evaluate where it is on the sigmoid curve, and an accelerated expansion test is one way to do so.[965]

As discussed above, NextEra witness Mr. Sherman testified that NextEra knows where it is on the sigmoid curve because both the petrography and elastic modulus indicate Seabrook is

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[960] Id. at 137; see Tr. at 1117–18 (Philip) ("[Mortar bars are] small samples without the structural context in place.").

[961] Ex. NER003, MPR Testimony, Proprietary Appendix at 2 tbl.3 n.3 (non-public).

[962] Ex. NER001, MPR Testimony at 137.

[963] Id. at 138.

[964] Tr. at 385–86 (Saouma).

[965] Tr. at 386, 415 (Saouma).

in the active phase of the curve.[966] According to Mr. Sherman, Seabrook's location on the sigmoid curve is continually monitored through the expansion monitoring with pins and through visual monitoring.[967] NextEra witness Mr. Bagley testified that "the petrographic examinations done by SG&H, and then the rate monitoring that has been done over time [by the SMP], provides the best estimate . . . for where the plant is on the [sigmoid] curve."[968]

4. Findings of Fact and Board Analysis

While C-10 recommends an alternative method for evaluating ASR at Seabrook, we conclude that NextEra has shown by a preponderance of the evidence that NextEra's approach to measuring ASR and its structural impact provides reasonable assurance and does not require supplementation by an accelerated expansion test. C-10 has failed to demonstrate that the current method of in-situ monitoring against threshold limits established in the LSTP is insufficient and does not provide reasonable assurance that it will effectively monitor ASR.

a. Ultimate ASR Expansion/Representativeness

NextEra's chosen monitoring approach does not require a determination of the ultimate ASR expansion. A centerpiece of NextEra's ASR monitoring program is its monitoring intervals, which vary depending on the severity of ASR degradation in a given structure.[969] As long as the monitoring intervals are sufficient (discussed supra Part VIII.B), there is no need to determine ultimate expansion. C-10 failed to proffer any evidence that would establish the need for an artificially high (likely by several orders of magnitude) expansion limit of the concrete. As NextEra witnesses testified, "the only need for understanding [the] rate of expansion at

[966] Tr. at 389–91 (Sherman).

[967] Tr. at 391 (Sherman).

[968] Tr. at 401 (Bagley).

[969] See Ex. INT010, Original LAR at PDF 65–66.

Seabrook is validation that the monitoring frequency is sufficient, and NextEra is using in-situ monitoring for this purpose."[970]

We also emphasize that NextEra determined the expansion potential of Seabrook concrete by using a reactivity test.[971] With the reactivity test, NextEra determined that the expansion potential of actual Seabrook concrete to be greater than 7.0 mm/m (0.7%), which means that the expansion may exceed the threshold limits provided in the LAR and monitored in the SMP.[972] Therefore, NextEra assumes that in-situ monitoring will continue for the licensing term and that the ultimate expansion potential will exceed the threshold limits established by the LSTP.[973] NextEra indicated it expects to exceed the through-thickness expansion limit in the most severe areas by [redacted].[974] Thus, NextEra acknowledged that ASR will expand at Seabrook throughout the life of the plant and has incorporated those assumptions into the monitoring program accordingly.

Furthermore, we note that an accelerated expansion test is a destructive test. Therefore, it must provide significant and useful data to justify its use. We find that an accelerated expansion test would not provide useful data regarding ultimate ASR expansion because NextEra assumes that ASR expansion will continue for the duration of the plant's licensed operation, based on the expansion data from the reactivity test.[975]

Regarding the use of accelerated expansion tests to confirm that LSTP concrete is, or is not, representative of Seabrook, the Board finds that because the concrete mixture design of the LSTP test specimens was made intentionally susceptible to ASR, its reactivity as measured

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[970] Ex. NER001, MPR Testimony at 152.

[971] Id. at 137–38.

[972] Id. at 137.

[973] Id.

[974] Ex. NER003, MPR Testimony, Proprietary Appendix at 2 tbl.3 n.3 (non-public).

[975] Ex. NER001, MPR Testimony at 137.

by an accelerated expansion test would be different from the reactivity of the Seabrook concrete by design. As a result of this, the performance of accelerated expansion tests would not provide useful information regarding whether the LSTP concrete is representative of the Seabrook concrete.

b. Monitoring Intervals and Sigmoid Curve

Because NextEra assumes that ASR will expand for the duration of the licensing term,[976] NextEra will continuously monitor ASR-affected structures, with the most severely affected structures currently monitored every six months.[977] If the SMP indicates a significant increase in the expansion rate, NextEra will need to increase its monitoring frequency in accordance with the Board's license condition, an approach we have found sufficient to provide reasonable assurance of adequate protection of public health and safety, supra Part VIII.B.3. C-10 failed to explain how or why an accelerated expansion test would provide significant or useful data that otherwise could not be obtained by the monitoring program. We note that NextEra has already assumed it is in the active portion of the sigmoid curve[978] and that it is monitoring both the expansion and the rate of expansion. NextEra is in essence developing the expansion curve using actual plant data rather than a laboratory-based test

Our review of the relevant record documents supports the conclusion that accelerated expansion tests are not necessary at Seabrook. Both the EPRI Report and the FHWA Report indicate that the best method to determine the rate of expansion for a given Seabrook structure is in-situ monitoring for expansion and deformation performed at selected frequencies.[979] The FHWA Report states that "[t]he potential for further expansion due to ASR is a critical parameter

[976] Id. at 137–38.

[977] See Ex. INT010, Original LAR at PDF 65.

[978] Tr. at 421–22 (Sherman).

[979] See Ex. NER013, FHWA Report at 26–27; Ex. NER017, EPRI Report at 2-15 (non-public).

to consider when selecting the most appropriate remedial action(s) for concrete affected by ASR."[980] Further, the FHWA Report states that "[c]urrent rates of expansion are best established from periodic or continuous in-situ monitoring of deformations, which can then be extrapolated for estimating the potential for future expansion."[981] However, that report continues, such a method may take two to three years to "yield useful information[.]"[982]

The EPRI Report echoes the FHWA Report's conclusions that in-situ monitoring is an accurate method to monitor the ASR expansion. Specifically, the EPRI Report states that "[m]onitoring the deformation in the field is considered as the most accurate method for evaluating the current rate of expansion[.]"[983] Consistent with the FHWA Report, the EPRI Report justifies this conclusion by demonstrating that "deformation monitoring should be performed for at least [two] to [three] years to account for temperature and moisture variations in the field."[984] In recommending in-situ monitoring, the EPRI Report emphasized several drawbacks of laboratory tests such as accelerated expansion tests.[985]

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[980] Ex. NER013, FHWA Report at 26.

[981] Id.

[982] Id. at 26–27 ("However, in-situ monitoring will generally take a minimum of 2 and preferably 3 years to yield useful information, i.e., where permanent and cumulative deformation due to ASR could 'reliably' be differentiated from reversible and cyclic movements related to mechanical (loading, traffic, operation conditions, etc.), thermal and climatic (daily and seasonal) variations.").

[983] Ex. NER017, EPRI Report at 2-15 (citations omitted) (non-public).

[984] Id. (non-public).

[985] Id. at 2-17 ("There may be difficulties in measuring the total ASR expansion in cores because the duration of these tests is not long enough to allow full consumption of reactive silica within the aggregates[;] Alkali leaching during the test underestimates the ASR expansion potential[;] The stress condition in field structures is different from that of cores[;] The residual expansion measured from cores does not account for the effects of reinforcement and loading in field structures. The level of reinforcement and the direction of the reinforcement are key parameters governing the extent of expansion observed in the field and cannot be accounted for in laboratory testing[;] Inconsistent humidity condition during long-term testing (for example, 1–2 years) can cause variation in ASR expansion[;] Several cores must be taken from different locations and along different directions within structures to represent different conditions of

According to the EPRI Report, accelerated expansion tests, by themselves, are not reliable indicators of future ASR expansion because there are several significant variables. For instance, "expansion tests on cores can provide only an indication on the future potential of ASR reaction (free residual expansion)."[986] Instead of using accelerated expansion tests, the EPRI Report suggests a combination of testing and monitoring is necessary "to predict the actual behavior of ASR-affected structures[.]"[987]

Additionally, the ISE document emphasizes that structural behavior, rather than the specific kinetic reaction of ASR, is the primary concern in measuring ASR.[988] The ISE document reaches this conclusion by emphasizing that there is not a uniform expansion rate within a given structure.[989] Stressing instead that there may be "substantial differences" because "[s]ome pours [within one structure or wall] may show no apparent damage while others may be severely damaged by cracking."[990] As a result, the ISE document concluded measuring the "structural [behavior] on site provides the best indication of rates of deterioration and when the rate of ASR damage is slowing."[991]

The Board also agrees with NextEra that, because unconfined concrete would be used for an accelerated expansion test, such tests would not be representative of conditions at

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ASR. This requires careful investigation to select cores from the most and least affected zones.") (non-public).

[986] Id. (non-public).

[987] Id. ("A combination of laboratory testing, structural monitoring (for instance, deformation, temperature, humidity, and confined stresses), and information from structures (for example, reinforcement detailing and boundary conditions) should be used to develop calibrated numerical models to predict the actual behavior of ASR-affected structures[.]" (citations omitted)) (non-public).

[988] Ex. NER012, ISE Structural Effects of [ASR] at 31 (non-public).

[989] Id. (non-public).

[990] Id. (non-public).

[991] Id. (non-public).

Seabrook. Dr. Saouma stated in response that extracted cores were used for other tests.[992] This argument is unpersuasive. The fact that NextEra used extracted cores for other purposes does not make them representative for the purposes of accelerated expansion tests. Because the in-situ cores, after being subjected to accelerated expansion, would be unrepresentative of Seabrook concrete, we fail to see how that data could influence the monitoring intervals, which are based on actual data from the plant.

c. Threshold Expansion/Acceptance Limits

We find no need to conduct an accelerated expansion test to indicate whether Seabrook structures will exceed the acceptance limits. NextEra conducted a reactivity test and concluded ASR would expand for the duration of the licensing term.[993] Also, NextEra calculated that the through-thickness expansion limit would be reached in [redacted], assuming linear ASR expansion.[994] Problems with non-representativeness aside, there is no need to perform a test to determine whether the acceptance limits will be exceeded when NextEra already assumes that the expansion limits likely will be reached during the licensing term. In effect, an accelerated expansion test cannot tell NextEra anything it does not already know with regard to the acceptance limits.

The primary goal of the Seabrook in-situ monitoring program in the SMP is to assure that the acceptance limits established under the LSTP, as documented in the LAR and implemented in the SMP, are not exceeded.[995] A preponderance of the evidence indicates that the use of

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[992] Tr. at 384–85 (Saouma).

[993] Ex. NER001, MPR Testimony at 137–38.

[994] Ex. NER003, MPR Testimony, Proprietary Appendix at 2 tbl.3 n.3 (non-public).

[995] See Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 1-1.1 (non-public); Ex. NER001, MPR Testimony at 128 ("[T]he purpose of the SMP—and any aging management program—is to monitor the aging mechanism so that the plant can take action to address the condition before it continues outside of the licensing basis. The SMP at Seabrook fulfills this function by using a classical aging management approach to monitor parameters to specified acceptance criteria and take action prior to exceeding those criteria.").

periodic in-situ expansion monitoring, conducted under the SMP, is the best method to measure the current rates of expansion and, by extrapolation, the potential for future expansion according to the FHWA Report, which Dr. Saouma references in his hearing testimony.[996] The in-situ monitoring program at Seabrook will be in place for the duration of the licensing term, which is significantly longer than the minimum two or three years needed for such monitoring to account for natural cyclic variations.[997]

While accelerated expansion testing might be a useful addition to the development of the calibrated numerical models discussed above,[998] it is not required, and there is no evidence indicating it would be helpful to support the in-situ monitoring approach selected by NextEra and described in the LAR.[999] Dr. Saouma testified that his other suggested methods ("periodic [DRI] measurements, detailed petrographic studies, and modern computational methods") are "demonstrably effective."[1000] But C-10 proffered no other evidence demonstrating that NextEra's in-situ monitoring is "demonstrably ineffective."[1001] Although Dr. Saouma testified that his suggestions are not just "a different way to do the job,"[1002] the Board finds by a preponderance of the evidence that the best method of determining the current rate of expansion is in-situ monitoring of the structures. We therefore agree with the Staff and NextEra that there is no need to perform accelerated expansion tests in support of the SMP.

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[996] Ex. NER013, FHWA Report at 26.

[997] Id. at 26–27.

[998] See supra notes 931–932 and accompanying text.

[999] See Ex. NER001, MPR Testimony at 137–38; Ex. NRC001-R, Staff Testimony at 71–72.

[1000] Ex. INT032, Dr. Saouma Rebuttal Testimony at 9.

[1001] Id.

[1002] Id.

D. Corroboration Study

The Corroboration Study forms the technical basis for the SMP.[1003] Simply described, when an extensometer is inserted into the Seabrook concrete according to the SMP guidelines to track future through-thickness expansion, NextEra needs to know the amount of expansion that has occurred from the time that the plant was constructed until the time that the extensometer is inserted.[1004] NextEra implemented a methodology for calculating initial expansion by using an empirical correlation developed during the LSTP.[1005] The methodology determines through-thickness expansion from the normalized elastic modulus.[1006] The latter is the ratio of the measured elastic modulus when the extensometer is installed to the elastic modulus twenty-eight days from original casting of the concrete during Seabrook's construction.[1007] Though the elastic modulus was not measured during plant construction, compressive strength was measured, and NextEra stated that the elastic modulus can be calculated from the compressive strength using the ACI 318-71 empirical formula.[1008] Although NextEra considered another approach for obtaining the original elastic modulus by extracting and measuring cores at representative ASR-free Seabrook locations,[1009] it decided instead to use the compressive strength methodology.[1010]

[1003] Tr. at 1012 (Buford).

[1004] Ex. NER001, MPR Testimony at 121.

[1005] Id. at 117–19.

[1006] Id.

[1007] Ex. INT018-R, MPR-4153, Rev. 3 at 3-4.

[1008] Id. § 3.3.1; Ex. INT020, MPR-4153, Rev. 3 § 3.3.1 (non-public); Ex. NRC049, ACI 318-71 § 8.3 (non-public).

[1009] Ex. INT018-R, MPR-4153, Rev. 3 at iv, § 4; Ex. INT020, MPR-4153, Rev. 3 at iv, § 4 (non-public).

[1010] Tr. at 751 (Bagley).

Dr. Saouma challenged the Corroboration Study that NextEra is required to conduct to ensure that the through-thickness expansion of Seabrook's concrete can be derived from a measurement of the concrete's elastic modulus in accordance with a correlation equation just as was done during the LSTP.[1011] Specifically, Dr. Saouma testified that the identified problems in the Corroboration Study are too great for it to be reliable.[1012]

NextEra witnesses testified that the approach it adopted for the Corroboration Study is supported by the literature, which states that the elastic modulus decreases with the progression of ASR, and researchers have investigated this phenomenon quantitatively.[1013] In fact, NextEra quoted the EPRI Report as concluding "that the modulus of elasticity is the best indicator for ASR progress."[1014] NextEra decided to use the LSTP data to produce its own correlation rather than rely on the literature in order to improve representativeness by utilizing specimens that "ha[d] a reinforcement configuration . . . comparable to structures at Seabrook.[1015] Finally, NextEra asserted that it applied a reduction factor of [redacted] to the normalized elastic modulus input,[1016] which increases the calculated effect of ASR degradation, causing the estimated through-thickness expansion to be higher than it would be if the reduction factor were not applied. According to NextEra witnesses, this approach rendered the revised correlation more conservative, since it reduces the margin to the acceptance criteria derived

[1011] Tr. at 514–15, 771 (Saouma); Ex. INT028, Dr. Saouma Rebuttal Testimony at 36–41 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36–41; Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4.

[1012] Ex. INT028, Dr. Saouma Rebuttal Testimony at 36–41 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36–41; Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4.

[1013] Ex. NER001, MPR Testimony at 118–19.

[1014] Ex. NER017, EPRI Report at 4-1, 4-2 fig.4-1 (non-public).

[1015] Ex. NER001, MPR Testimony at 118–19.

[1016] Ex. INT018-R, MPR-4153, Rev. 3 § 4.2.2; Ex. INT020, MPR-4153, Rev. 3 § 4.2.2 (non-public).

from the LSTP.[1017] Thus, for the purpose of determining total through-thickness expansion at any future date after extensometer insertion, NextEra will use the sum of the calculated expansion from the time of construction until extensometer insertion using the revised modulus correlation and the future expansion as measured by the extensometer.[1018]

NextEra witnesses provided the following description of the Corroboration Study:

> The [C]orroboration [S]tudy will occur several years after installation of the extensometers to allow time for through-thickness expansion to occur. Fundamentally, the approach for the [C]orroboration [S]tudy includes four steps: (1) estimate pre-instrument expansion using the correlation when the extensometer is installed to establish a point of reference, (2) monitor through-thickness expansion using the extensometer as specified in the SMP, (3) after several years of monitoring, obtain another core from the same general vicinity and test for elastic modulus to re-determine through-thickness expansion, (4) compare the change in expansion from the original point of reference using the new elastic modulus data and the extensometer data. Successful corroboration would show comparable results using the two methods. At the time of the study, NextEra will obtain new cores from the vicinity of 20% of the extensometers.[1019]

The Staff agreed with NextEra's approach and imposed a license condition that requires the study to cover at least 20% of extensometer locations on ASR-affected structures.[1020] NextEra must complete the initial study no later than 2025 and a complete follow-up study 10 years thereafter.[1021] According to the Staff:

> [I]f there is [an] indication that the LSTP results do not apply to Seabrook structures, then NextEra would be required to conduct prompt operability determinations to determine whether the structures remain operable or, if they do not, shut down the facility, as dictated by the facility's technical specifications; these activities would be subject to NRC oversight.[1022]

[1017] Ex. NER001, MPR Testimony at 120; Ex. NER003, MPR Testimony, Proprietary Appendix at 9 fig.10 (non-public).

[1018] Ex. NER001, MPR Testimony at 120.

[1019] Id. at 121; see Ex. INT019, MPR-4273, app. C; Ex. INT021, MPR-4273 app. C (non-public).

[1020] Ex. INT024, Final SE at PDF 68–69; Ex. NRC001-R, Staff Testimony at 43.

[1021] Ex. INT024, Final SE at PDF 68–69.

[1022] NRC Staff's Proposed Findings of Fact and Conclusions of Law at 25; see Tr. at 719–20 (Buford, Lehman), 739–42 (Buford), 1012 (Buford).

Because the Corroboration Study forms part of a license condition for the LAR,[1023] it cannot be changed without NRC approval.[1024] Moreover, it includes a specific provision to notify the NRC each time a corroboration action is completed.[1025]

1. C-10's Prima Facie Case

Dr. Saouma testified that the change in elastic modulus cannot reliably determine what has been the past through-thickness expansion in Seabrook's concrete.[1026] Moreover, he stated that each step of the Corroboration Study carries "substantial uncertainties[.]"[1027] As an example, he claimed that there are numerous uncertainties associated with NextEra's use of the compressive strength measurement from Seabrook's construction to estimate elastic modulus 28 days from casting.[1028]

Dr. Saouma testified that a major problem with the procedure by which NextEra calculated the normalized elastic modulus from the 28-day compressive strength is "that concrete compressive strength increases over time (due to the hydration of the cement), with most of the increase occurring [in] the first few years."[1029] Dr. Saouma stated that failure to account for this increase would cause NextEra to underestimate the through-thickness expansion.[1030] To support this claim, C-10 introduced a textbook source that showed the

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[1023] Ex. NRC001-R, Staff Testimony at 43; Ex. INT024, Final SE at PDF 68–69; see Ex. NER001, MPR Testimony at 61–62.

[1024] Ex. NRC001-R, Staff Testimony at 29.

[1025] Ex. INT024, Final SE at PDF 68; Ex. NER001, MPR Testimony at 62–63.

[1026] Tr. at 771 (Saouma).

[1027] Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4; see Ex. INT028, Dr. Saouma Rebuttal Testimony at 36–41 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36–41.

[1028] Tr. at 514–15 (Saouma).

[1029] Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1.

[1030] Id.

compressive strength of a specified concrete sample is 20% higher after five years than the reference value measured at 28 days.[1031]

Dr. Saouma further testified that another source of uncertainty in the NextEra study is the correlation between the normalized elastic modulus and through-thickness expansion, which "is based on few test data at the [LSTP] and . . . have an inherent variability."[1032]

Dr. Saouma also disagreed with NextEra's use of the B Electrical Tunnel as the appropriate reference location for comparing Seabrook's concrete to the specimens used in the LSTP. C-10 noted there is a substantial difference between the measured 28-day compressive strengths at that tunnel versus the CEB and that this renders the LSTP tests not representative of the most critical part of the Seabrook reactor.[1033]

Finally, Dr. Saouma stated that since there are so many uncertainties in the Corroboration Study, the figures containing the data and curves should contain "error bars[.]"[1034]

2. NextEra and Staff Responses

NextEra witnesses asserted that it compared data from the literature to data from the LSTP and confirmed that the trends are comparable and provide reasonable assurance that the modulus correlation can be applied at Seabrook.[1035]

NextEra witnesses not only agreed with C-10 that the compressive strength increases with time just after the concrete is cast, but also agreed that it is a well-known phenomenon

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[1031] Id. at 1, 2 fig.1; Ex. NRC073, David Darwin, Charles W. Dolan, and Arthur H. Nilson, "Design of Concrete Structures" (McGraw Hill, Inc., 15th Ed. 2016) at 38 fig.2.5 [hereinafter Ex. NRC073, Darwin, et. al.] (non-public); Tr. at 747–50 (Saouma).

[1032] Ex. INT028, Dr. Saouma Rebuttal Testimony at 36–41 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36–41; Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4.

[1033] Tr. at 1144–46 (Saouma).

[1034] Tr. at 1146 (Saouma).

[1035] Ex. NER001, MPR Testimony at 118–20.

discussed in many textbooks.[1036] Additionally, NextEra witnesses agreed with Dr. Saouma that the increase is rapid early on, but that later it "decreases rapidly to the point where it effectively plateaus [with] no difference in [aging] at that point."[1037] NextEra witness Dr. Bayrak conceded that compressive strength increases approximately 15-20% after the first twenty-eight days.[1038] However, Dr. Bayrak testified that over time, in terms of actual behavior, not calculations, the elastic "modulus matures much earlier than [does] compressive strength[.]"[1039] Dr. Bayrak stated that since NextEra did not measure the elastic modulus at the time of construction, it had to use the compressive strength measurements available at that time.[1040]

NextEra witnesses stated that the evidence clearly establishes that NextEra adequately addressed any uncertainty in the elastic modulus correlation.[1041] As for C-10's assertion that the compressive strength initially increases due to the hydration of the cement, with most of the increase occurring the first few years, NextEra witnesses stated that the modulus correlation inherently accounts for that effect.[1042] NextEra witnesses further stated that since the test data it used to determine the correlation were from concrete that had cured to the point that the increase in compressive strength either had already been realized for the great majority of the data or, in the case of three data sets, was insignificantly different from being fully realized.[1043]

[1036] Ex. NER076, Testimony of NextEra Witnesses John Simons, Christopher Bagley, Oguzhan Bayrak, and Edward Carley in Response to Exhibit INT030 at 6 [hereinafter Ex. NER076, NextEra Response to Ex. INT030-R] (non-public).

[1037] Tr. at 749–50 (Bagley); Ex. NER076, NextEra Response to Ex. INT030-R at 6–7 (non-public).

[1038] Tr. at 752–53 (Bayrak).

[1039] Tr. at 753 (Bayrak).

[1040] Tr. at 756 (Bagley).

[1041] Ex. NER076, NextEra Response to Ex. INT030-R at 4 (non-public); Ex. INT018-R, MPR-4153, Rev. 3 § 4.2; Ex. INT020, MPR-4153, Rev. 3 § 4.2 (non-public).

[1042] Ex. NER076, NextEra Response to Ex. INT030-R at 2 (non-public).

[1043] Id. at 2, 8 (non-public).

Thus, NextEra maintained that no adjustments to the modulus correlation were necessary "to account for differences in hydration of the cement as a function of time."[1044]

NextEra witness Mr. Carley testified that NextEra currently has forty-eight extensometers installed and the Corroboration Study would pull cores from 20%, i.e. approximately ten of those locations.[1045] More specifically, in order to increase the conservatism in the methodology, NextEra plans to examine the data from those forty-eight extensometers and choose the 20% showing the highest level of expansion, which should show the greatest agreement with the correlation curve.[1046] Moreover, NextEra will introduce a reduction factor of [redacted] to the normalized elastic modulus to increase the calculated degradation, or through-thickness expansion.[1047] In addition, NextEra witness Mr. Bagley stated that NextEra would take a look at all the data points to see what makes the most sense for executing the Corroboration Study.[1048]

NextEra witness Mr. Carley testified that if the Corroboration Study does not confirm consistency with the LSTP modulus correlation results, it will implement the Corrective Action Program.[1049] Although NextEra does not know currently what corrective actions it would take, it would proceed under NRC oversight.[1050]

The Staff challenged several of Dr. Saouma's assertions regarding the modulus correlation together with the measured elastic modulus to determine the through-thickness expansion at Seabrook. For example, Dr. Saouma faulted a lack of error bars in displaying the

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[1044] Id. at 2 (non-public).

[1045] Tr. at 1009 (Carley).

[1046] Tr. at 1013–14 (Carley).

[1047] Ex. NER076, NextEra Response to Ex. INT030-R at 4–5 (non-public); see Ex. INT018-R, MPR-4153, Rev. 3 § 4.2.2; Ex. INT020, MPR-4153, Rev. 3 § 4.2.2 (non-public).

[1048] Tr. at 1015 (Bagley).

[1049] Ex. INT024, Final SE at PDF 68; Tr. at 1009–10 (Carley).

[1050] Tr. at 1010 (Carley, Lehman).

results of the modulus correlation and data.[1051] The Staff disagreed and stated that the correlation is used in the context of the design basis codes, which do not use error bars but incorporate "normal variability" into their equations.[1052]

The Staff likewise disputed C-10's argument that the correlation fails to account for the increase in compressive strength of concrete over time, and thus would underestimate through-thickness expansion. In this regard, Dr. Saouma stated that the compressive strength after five years could be as much as 20% higher than the value measured at 28 days.[1053] According to the Staff's analysis, even if this were the case at Seabrook, NextEra's [redacted] reduction factor would bound this uncertainty.[1054]

3. Findings of Fact and Board Analysis

First, the Board notes that there has been some confusion as to what constitutes the Corroboration Study. According to NextEra, Dr. Saouma's Supplemental Rebuttal Testimony conflated the modulus correlation and the Corroboration Study, which NextEra stated are two different concepts.[1055] NextEra called attention to Dr. Saouma's alleged misunderstanding and expressly identified the differences between these two concepts. According to NextEra "the modulus correlation is used to estimate the through-thickness expansion at Seabrook before an extensometer is installed[,]"[1056] whereas "[t]he [C]orroboration [S]tudy is an approach for

[1051] Tr. at 797 (Saouma).

[1052] Ex. NRC090, Staff Testimony in Response to Exhibit INT030 at 4 [hereinafter Ex. NRC090, Staff Testimony in Response to Ex. INT030-R] ("Dr[.] Saouma mischaracterizes normal variability in the data underlying the code equation as a margin of error in the code equation.").

[1053] Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1.

[1054] Ex. NRC090, Staff Testimony in Response to Ex. INT030-R at 5–6.

[1055] Ex. NER076, NextEra Response to Ex. INT030-R at 2 (non-public).

[1056] Id.

obtaining in-plant data to evaluate how expansion at the plant aligns with observed expansion of the LSTP specimens."[1057]

Because C-10's challenge pertains to NextEra's method of estimating pre-extensometer through-thickness expansion, we interpret it as a challenge to the modulus correlation, not the Corroboration Study.[1058] The Board does not agree with NextEra's assessment that Dr. Saouma misunderstood the difference between the modulus correlation and the Corroboration Study. In fact, Dr. Saouma explicitly stated that "[t]he [C]orroboration [S]tudy is used 'to evaluate how expansion at the plant aligns with observed expansion of the LSTP specimens.'"[1059] Further, Dr. Saouma also highlighted the following NextEra description of the study: "'the [C]orroboration [S]tudy focuses on a correlation developed during the LSTP that is used by NextEra to estimate through-thickness expansion at Seabrook before an extensometer is installed.'"[1060] Thus, we find that Dr. Saouma fully understood the difference between the modulus correlation and the Corroboration Study, and C-10 focused its comments on the modulus correlation as a critical element of the Corroboration Study.

NextEra's proposed ASR expansion monitoring program was "a first-of-a-kind" approach, and as a result, the Staff imposed a license condition on the LAR that requires NextEra to confirm the continued applicability of the LSTP to ASR-affected structures at Seabrook.[1061] To ensure continued applicability, the Corroboration Study will cover at least 20% of the extensometer locations on the worst ASR-affected structures.[1062] NextEra will complete

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[1057] Ex. NER001, MPR Testimony at 62.

[1058] See Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4.

[1059] Id. at 1 (quoting Ex. NER001, MPR Testimony at 62).

[1060] Ex. INT032, Dr. Saouma Rebuttal Testimony at 36 (quoting Ex. NER001, MPR Testimony at 62).

[1061] Ex. INT024, Final SE at PDF 40, 67–69; Ex. NER001, MPR Testimony at 61–62.

[1062] See Tr. at 1009, 1013–14 (Carley).

the initial study no later than 2025 and a follow-up study ten years thereafter.[1063] If there is any indication that the LSTP results do not continue to apply to Seabrook structures, then NextEra will be required to conduct, under NRC oversight, prompt operability determinations, and if needed, pursue corrective actions, including facility shutdown.[1064]

Dr. Saouma stated that there are so many uncertainties involved in the modulus correlation as implemented that it puts the entire Corroboration Study in jeopardy.[1065] One of C-10's biggest challenges concerns what it perceived to be NextEra's failure to take into account early cement hydration, which causes the compressive strength to increase just after casting and continue for some time afterward.[1066] If true, this could invalidate NextEra's approach. However, NextEra witnesses testified that NextEra properly accounted for this effect in its analysis.[1067] Also, both Staff and NextEra witnesses testified that the [redacted] normalized elastic modulus reduction factor allows sufficient conservatism in the analysis to account for this effect.[1068]

After careful consideration of the parties' arguments, the Board finds C-10's arguments unpersuasive. The Corroboration Study is a critical part of the LAR, because it allows NextEra periodically to ascertain whether the results of the LSTP remain relevant for the continued

[1063] Ex. INT024, Final SE at PDF 68–69.

[1064] Id. at PDF 68; Tr. at 719–20 (Buford, Lehman), 739–42 (Buford, Simons), 1012–13 (Buford, Bagley).

[1065] Ex. INT028, Dr. Saouma Rebuttal Testimony at 36–41 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36–41; Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1–4.

[1066] Ex. INT030-R, Dr. Saouma Supp. Rebuttal Testimony at 1.

[1067] Ex. NER076, NextEra Response to Ex. INT030-R at 2 (non-public).

[1068] Ex. NER001, MPR Testimony at 120; Ex. NER003, MPR Testimony, Proprietary Appendix at 9 fig.10 (non-public); Ex. INT018-R, MPR-4153, Rev. 3 § 4.2.2; Ex. INT020, MPR-4153, Rev. 3 § 4.2.2 (non-public); Ex. NRC090, Staff Testimony in Response to Ex. INT030-R at 5–6.

monitoring of Seabrook seismic Category I structures.[1069] Therefore, the Board agrees with NextEra and the Staff, and based upon a preponderance of the evidence, it finds that NextEra's approach to the Corroboration Study, including the modulus correlation, provides reasonable assurance of adequate protection.

E. Concrete Delamination and Localized Excursions Outside the Linear Elastic Regime

Delamination occurs when laminate or solid structures split or separate.[1070] This gradual separation creates internal cracks in the structure, or in Seabrook's case, the concrete.[1071] Both cracks that are hidden below the surface and cracks that manifest on the surface could indicate hazardous delamination.[1072]

During the process of delamination, microcracks become macrocracks that tend to run parallel to the direction of the restraint.[1073] Microcracks reduce the mechanical and material properties of ASR-affected concrete (compressive strength, elastic modulus, tensile strength, shear strength, and flexural strength) and may reduce its structural capacity.[1074] Delamination takes the form of mid-plane cracks.[1075] Generally, ASR expansion occurs in three orthogonal directions.[1076] When there is a confinement of the concrete in two orthogonal directions, the

[1069] Ex. INT024, Final SE at PDF 67–69.

[1070] See Ex. INT027, Dr. Saouma Pre-Filed Testimony at 17 fig. 10.

[1071] Tr. at 556–57 (Saouma).

[1072] Tr. at 1141 (Saouma).

[1073] Ex. NER012, ISE Structural Effects of [ASR] at 13 (non-public); Tr. at 770, 890–91 (Saouma).

[1074] Ex. NRC001-R, Staff Testimony at 7; see Tr. at 573–74 (Saouma).

[1075] Tr. at 770 (Saouma).

[1076] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 6 ("If unimpeded, ASR expansion is volumetric and isotropic (i.e., the same amount of expansion occurs in three directions or 'planes')."); see Ex. NER001, MPR Testimony at 121; Ex. NER004, SGH Testimony at 66.

ASR expansion will plateau in those directions and then reorient along the unconfined direction.[1077] This process instigates the delamination.

If delamination poses a problem for the operation of Seabrook, then the problem could be exacerbated if Seabrook's operational parameters experience localized excursions outside the linear elastic regime,[1078] which is one of Dr. Saouma's concerns.[1079] According to the ASME and ACI 318-71 design codes, the responses to stresses on the structural components at Seabrook are generally assumed to be elastic.[1080] However, during their testimony both NextEra and the Staff stated that this may not always be the case for localized regions of Seabrook.[1081] Therefore, excursions of Seabrook outside the linear elastic regime deserve careful attention.

1. Motion in Limine

NextEra moved to exclude C-10's testimony concerning the longitudinal crack exhibited in the LSTP. Specifically, NextEra moved to exclude Dr. Saouma's pre-filed testimony section C.2.3.2 and Dr. Saouma's rebuttal testimony sections D7.1 and D7.2 as these "challenges relate[] to the execution of the LSTP that could have been, but were not, raised at the outset of

[1077] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 6.

[1078] Linear elastic regime, or linear elastic behavior, refers to conditions under which a structure returns to its original configuration when loads are removed. See Ex. NER004, SGH Testimony at 52.

[1079] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 7, 32; Ex. INT032, Dr. Saouma Rebuttal Testimony at 43; Tr. at 869–70, 1056 (Saouma).

[1080] Tr. at 303 (Bell), 869 (Thomas); Ex. NER001, MPR Testimony at 133–34; Ex. NER004, SGH Testimony at 52–56; Ex. INT024, Final SE at PDF 57.

[1081] Tr. at 728–29 (Bolourchi), 868–69 (Bell), 869 (Thomas), 1085 (Thomas), 1091–93 (Thomas); Tr. at 864–65 (Bell) ("With respect to the ACI [318-71] code, the requirements are a little bit different. You are allowed some amount of plasticity in areas of high stress . . . So again, the codes of record limit how much plasticity there can be in the ACI code. The ASME code allows none.").

this proceeding."[1082] C-10 opposed the motion.[1083] We find that Dr. Saouma's arguments regarding the longitudinal crack in the LSTP are "fairly encompassed by the description of" the admissible contentions as he questions the representativeness of the LSTP.[1084] In this respect, NextEra's Motion in Limine is denied.

Dr. Saouma initially noted that the longitudinal crack "jeopardizes the representativeness of the ensuing test."[1085] Dr. Saouma likened the longitudinal crack to a delamination crack and "[t]herefore, the specimen that was tested cannot be considered representative as it was already damaged, and ensuing results would be unreliable."[1086] However, in Dr. Saouma's rebuttal testimony, he stated that the alleged delamination crack is in fact representative of Seabrook.[1087] Indeed, Dr. Saouma testified that the longitudinal crack "may have impacted the validity of the shear tests[,]" and, despite the alleged unreliability of the shear tests, "such a [delamination] crack . . . may form inside the walls of Seabrook."[1088] Further, Dr. Saouma stated that there is the "perfect storm" of variables at Seabrook for delamination to occur.[1089]

Without addressing the seemingly contradictory arguments in Dr. Saouma's pre-filed and rebuttal testimonies, we decline to exclude such testimony as it is "envelope[d]" within the bases

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[1082] NextEra MIL 2 at 17–18 (emphasis omitted). NextEra also moved to exclude Dr. Saouma's pre-filed testimony section C.2.3.1 (Load Displacement), however he withdrew that argument during the hearing. Id.; Tr. at 314 (Saouma); Ex. INT001-R, Dr. Saouma Pre-Filed Testimony § C.2.3.1 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.2.3.1.

[1083] C-10 Opp. to MIL 2 at 20.

[1084] Pilgrim, CLI-10-11, 71 NRC at 310.

[1085] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 16 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 16.

[1086] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 16 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 16.

[1087] Ex. INT028, Dr. Saouma Rebuttal Testimony at 26–33 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 26–33.

[1088] Ex. INT028, Dr. Saouma Rebuttal Testimony at 29 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 29.

[1089] Ex. INT032, Dr. Saouma Rebuttal Testimony at 30.

of the reformulated contention and directly related to the representativeness of the LSTP.[1090] As noted, but not repeated here,[1091] we decline to apply NextEra's narrow approach to defining the bases of the reformulated contention. Here, there is a plain connection between the presence of the longitudinal crack and representativeness. If, in fact, the longitudinal crack affected the results of the LSTP, the Board should consider such testimony. If the longitudinal crack rendered the LSTP data "unreliable" that would undoubtedly implicate representativeness.

In addition, the presence of the longitudinal crack is closely related to the issue raised by admitted Contention C, one of the bases of the reformulated contention. In Contention C, C-10 maintained that "[t]horough petrographic analysis, including core sample testing of Seabrook's in-situ concrete, must be integral to NextEra's assessment of the advance of ASR."[1092] C-10 argued in support of Contention C that petrographic analysis was needed to detect microcracking and that "[u]ntil thorough petrographic analysis is performed on Seabrook's concrete structures, NextEra has no real basis by which it can reassure . . . the NRC[ ] that Seabrook's ASR progression is truly understood."[1093] As explained below, Dr. Saouma testified that NextEra should perform petrographic analysis of concrete cores from Seabrook structures to detect microcracks, which eventually coalesce into larger cracks that may lead to delamination. That testimony falls within the scope of Contention C. Dr. Saouma's pre-filed and rebuttal testimony concerning the longitudinal crack in the LSTP also emphasized the risk of

[1090] See Catawba, LBP-04-12, 59 NRC at 391.

[1091] See supra Part VIII.A.2.a.

[1092] LBP-17-7, 86 NRC at 107 (quoting C-10 Petition at 6).

[1093] Id. at 108 (quoting C-10 Petition at 8).

delamination at Seabrook,[1094] and therefore further supports Contention C's demand for thorough petrographic analysis of Seabrook concrete cores.

We now address the persuasiveness of C-10's arguments concerning delamination.

2. C-10's Prima Facie Case

Dr. Saouma stated that changes in humidity and temperature may produce gradients within the Seabrook walls, and when coupled with Seabrook's rebar being located close to the surface, cracking on the surface of its walls will not be representative of cracking in the interior.[1095] Dr. Saouma testified that such "delamination is unlikely to be captured by an extensometer because of the 'patchy' nature of ASR hot-spots or pockets, and because there may not be corresponding surface in-plane cracks that can be detected by the CI method."[1096] Since "ASR is not homogeneous within the walls[,] . . . failure to capture that internal [micro and macro]crack[s] with extensometers[] does not mean that crack[s are not present] inside the wall."[1097]

Dr. Saouma testified that the "development of microcrack[s]" as a result of ASR "cannot be neglected."[1098] According to Dr. Saouma, NextEra's failure to detect microcracks without seeing surface damage is because they are indeed micro-sized cracks,[1099] where the descriptor "micro" means that they are too small to be observed with the naked eye.[1100]

[1094] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 15–17 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 15–17; Ex. INT028, Dr. Saouma Rebuttal Testimony at 26–33 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 26–33.

[1095] Tr. at 836–37 (Saouma); Ex. INT032, Dr. Saouma Rebuttal Testimony at 28, 31.

[1096] Ex. INT032, Dr. Saouma Rebuttal Testimony at 31.

[1097] Id.; see Tr. at 696 (Saouma).

[1098] Tr. at 1087 (Saouma); see Ex. NRC075, Deschenes, et al. at 12.

[1099] Tr. at 1086 (Saouma).

[1100] Tr. at 1140 (Saouma).

Dr. Saouma, quoting the literature, testified that the behavior of concrete "at high stresses and [at] fracture is influenced by microcracking and other discontinuit[ies]."[1101] Dr. Saouma further testified that "[t]he moment the concrete stress exceeds 0.45 [compressive strength], and never mind about ASR, there are microcracks, and we enter the non-linear regime. On top of that, even if you are below [0].45 [compressive strength], you have the non-linearity induced by the microcracking due to ASR."[1102]

Dr. Saouma suggested the possibility that the so-called "edge effect" cracks in the LSTP were symptomatic of delamination.[1103] In the case of delamination, the concrete wants to expand, but it is confined in two directions, with the only free direction being the through-thickness direction.[1104] The process starts as internal microcracking that coalesces into larger cracks.[1105] Over time, roughly seven years, complete delamination may occur.[1106] Dr. Saouma further testified that similar cracking could occur in the concrete at Seabrook, avoiding detection by NextEra under the current monitoring scheme.[1107]

In support, Dr. Saouma provided the example of the delamination crack between two reinforcing mats that occurred at the Crystal River nuclear containment.[1108] Although not

[1101] Tr. at 1102 (Saouma); see Ex. NRC073, Darwin, et. al. at 45 (non-public).

[1102] Tr. at 1093–94 (Saouma).

[1103] Ex. INT028, Dr. Saouma Rebuttal Testimony at 26–33 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 26–33.

[1104] Tr. at 1140–41 (Saouma).

[1105] Tr. at 534 (Saouma), 891 (Saouma), 1108–09 (Saouma); Ex. NER012, ISE Structural Effects of [ASR] at 13 (non-public); see Ex. NRC001-R, Staff Testimony at 12.

[1106] Tr. at 1140–41 (Saouma).

[1107] Tr. at 572, 1161–63 (Saouma); see Ex. INT028, Dr. Saouma Rebuttal Testimony at 26–33 (non-public); Ex. INT032, Dr. Saouma Rebuttal Testimony at 26–33.

[1108] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 16–17, 17 fig.10 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 16–17, 17 fig.10.

caused by ASR degradation, it points to the existence of delamination as a real-life phenomenon.[1109]

Dr. Saouma testified that petrography is one of the methods that NextEra could utilize to detect the existence of microcracking with its potential for delamination beneath the surface.[1110] As another method, Dr. Saouma stated that one could "[p]ut the specimen under direct tension to find out if the resulting tensile strength[] is below what is perceived to be the tensile strength. That would reflect the microcracking, which is inside."[1111]

Dr. Saouma questioned the lack of conservatism caused by inputting the same thermal expansion in all three directions into NextEra's FEA, thereby ignoring the fact that most of the expansion is in the through-thickness direction. According to Dr. Saouma, NextEra should have used an anisotropic (i.e., not the same in every direction) coefficient of thermal expansion.[1112] Even though NextEra stated that it used a relative value that it measured in each direction for its inputs,[1113] Dr. Saouma challenged this assertion. He stated that he could not find anywhere in the exhibits an indication that an anisotropic coefficient of thermal expansion for all three directions was used.[1114]

Dr. Saouma further asserted that localized excursions outside the linear elastic regime at Seabrook Unit 1 would be especially dangerous if delamination should occur and stated "[i]t only takes this one localized failure to trigger a massive damage. I'm not talking about a total

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[1109] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 16 ("Th[e longitudinal crack] is not unlike the delamination crack (between reinforcement mats) that occurred at Crystal River (though for entirely different cause)[.]").

[1110] Tr. at 1140 (Saouma).

[1111] Tr. at 573 (Saouma).

[1112] Tr. at 351 (Saouma); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 26; Ex. INT032, Dr. Saouma Rebuttal Testimony at 33, 41.

[1113] Tr. at 351, 1171–74 (Bolourchi); see Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 93 tbl.13.

[1114] Tr. at 351, 1172 (Saouma).

collapse. One localized point. Going into plastification which is not accounted for, that's it. [K]aput."[1115] Dr. Saouma also stated "[w]e need to define failure, because failure does not mean the collapse of the whole structure. We have localized failure. This is what is of concern. It's the localized failure which is going to lead to an unacceptable leakage."[1116]

To further complicate the issue of the possibility of localized failures, Dr. Saouma testified that the failure mode associated with combined ASR degradation and an earthquake is a shear failure, which is entirely different from steel yielding, which is the traditional flexure failure mode of a section under ultimate load.[1117] The latter gives plenty of warning, while shear failure is brittle with no indication that failure is about to occur.[1118]

Considering the above arguments, the Board finds that C-10 has provided sufficient expert testimony to satisfy its burden of going forward.

3. NextEra and Staff Responses

According to NextEra witnesses, "[e]xpansion reorientation in the through-thickness direction does not occur until sufficient in-plane expansion has produced chemical prestressing with the reinforcing bars. Therefore, [NextEra concluded that] cracking in the through-thickness direction would not occur without any symptoms of expansion in the in-plane directions."[1119] This conclusion is based in part on NextEra's observations in the LSTP. In that program, the specimens contained bi-directional reinforcement in the in-plane directions similar to Seabrook, and during the expansion monitoring, initially, expansion occurred at approximately the same

[1115] Tr. at 869–70 (Saouma). Plastification is a state in which a structure does not return to its original configuration when loads are removed.

[1116] Tr. at 821 (Saouma).

[1117] Tr. at 1058 (Saouma).

[1118] Id.

[1119] Ex. NER001, MPR Testimony at 164.

rate in all directions until the in-plane expansion reached a certain level, after which the expansion reoriented to occur primarily in the unreinforced through-thickness direction.[1120]

For the LSTP, NextEra witnesses testified that "ASR progression in the test specimens was monitored in several different ways and in many different locations."[1121] It "performed crack width summation on both sides of [a] test specimen, which provided in-plane expansion at the surface in two separate locations."[1122] NextEra witnesses stated that NextEra monitored through-thickness expansion "by through-specimen embedded rods on both sides of each specimen. While the results showed variability that is within the expected range for concrete, there were no indications of significant non-homogeneity within any test specimen."[1123] Insofar as LSTP specimens displayed structural cracks on the side faces[1124] both NextEra and the Staff attributed this to an edge effect, since the cracking only extended down a couple of inches to about where the rebar started.[1125] NextEra witnesses testified that there was no delamination observed in the LSTP.[1126]

NextEra witnesses testified that it never found a spot at Seabrook where the extracted concrete cores indicated worse cracking at depth within the cores beyond what was indicated at the surface.[1127] Moreover, NextEra witnesses testified that in previous studies of 200 cores taken from Seabrook, it found no substantial difference between near-surface cracking and

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[1120] Id. at 91 (citing Ex. NER003, MPR Testimony, Proprietary Appendix at 5 fig.4 (non-public)).

[1121] Id. at 94.

[1122] Id.

[1123] Id.

[1124] Tr. at 358 (Saouma), 360 (Bayrak).

[1125] Tr. at 565–69 (Bayrak), 1138–39 (Buford).

[1126] Tr. at 704 (Bayrak), 1139 (Thomas).

[1127] Tr. at 397 (Sherman), 556 (Bayrak), 572 (Carley), 700 (Sherman).

cracking below the level of the reinforcing steel within the core of the structure,[1128] as confirmed by both visual and petrographic examinations.[1129]

NextEra witnesses stated that finite element codes do not provide direct inputs for ASR expansion, but that thermal expansion can be used as a proxy, and therefore ASR strain is simulated by applying an equivalent thermal load to the concrete.[1130] Thus, NextEra witness Mr. Bell asserted that FEAs allow for consideration of self-straining forces like ASR with inputs for thermal load with expansion coefficients.[1131] According to NextEra:

> The ASR load inputs to these models are: (1) the internal in-plane ASR expansion of reinforced structural members, and (2) the pressure due to ASR expansion of the concrete fill. The internal ASR expansion is determined via the field-measured CI expansion strain; CI is measured in each of the in-plane orthogonal directions. CI represents an equivalent ASR strain.[1132]

The EPRI Report states that restrained expansion in one or more directions affects the development of ASR and results in anisotropic damage.[1133]

According to Staff witness Ms. Buford, the Staff has not "seen, in either the literature or the [LSTP], any evidence of there being no indications of ASR in the planar directions visible, and then significant ASR occurring through the thickness of the concrete."[1134] Ms. Buford further stated "[w]ith that preponderance of the evidence, we have reasonable assurance that there is not extensive damage happening that is not visible—that wouldn't be visible by either in-

[1128] Tr. at 455–56 (Sherman), 560 (Buford), 572 (Carley), 705 (Bayrak); 1097–98 (Bayrak).

[1129] Tr. at 455–56 (Sherman), 531–32 (Carley); Ex. NER001, MPR Testimony at 93.

[1130] Ex. NER004, SGH Testimony at 40, 66.

[1131] See Tr. at 861 (Bell).

[1132] Ex. NER004, SGH Testimony at 40.

[1133] Ex. NER017, EPRI Report at 4-1 (non-public).

[1134] Tr. at 1133 (Buford).

plane cracking or some sort of deformation, which is being monitored and managed in a separate program."[1135]

As for localized excursions outside the linear elastic regime at Seabrook Unit 1, both NextEra and Staff witnesses testified that this may indeed occur due to extreme loads, such as seismic loads.[1136] Moreover, Staff witness Dr. Thomas stated that such excursions are typical for the roughly 100 reactors operating around the country.[1137] The Staff also recognized, however, that ACI 318-71 addresses this issue by using a methodology called equivalent linear analysis.[1138] Also, NextEra witness Dr. Bolourchi testified, and the Staff agreed,[1139] that as for the containment at Seabrook Unit 1, which is designed according to ASME Section III, Division 2, "[t]he only situation where a containment goes beyond [the] elastic limit is under the accident temperature. The load combination involving the accident pressure by itself is within [the] elastic limit."[1140] For certain structures governed by the ACI 318-71 code, except for the CEB, some controlled excursions into the nonlinear plasticity regime in areas of high stress are allowed.[1141] The codes of record limit how much plasticity is permitted in the ACI code, while the ASME code allows none.[1142]

Staff witness Dr. Thomas stated that localized nonlinear excursions are manageable, because the design code ensures "that if [a Seabrook structure is] pushed to failure you get a

[1135] Tr. at 1133–34 (Buford).

[1136] Tr. at 729 (Bolourchi), 869 (Thomas), 1085 (Thomas), 1091 (Thomas).

[1137] Tr. at 1055–56 (Thomas).

[1138] Tr. at 728–29 (Bolourchi), 1055 (Thomas).

[1139] Tr. at 869 (Thomas).

[1140] Tr. at 729 (Bolourchi).

[1141] Tr. at 728–29 (Bolourchi), 864–65 (Bell), 868–69 (Bell).

[1142] Tr. at 864–65 (Bell).

ductile failure, which means your steel should yield first rather than concrete failing in compression."[1143]

According to NextEra, if any limits in the ASR expansion monitoring program are approached, it then will perform reanalysis or remediation, as necessary.[1144] Staff witnesses stated that if Seabrook ever approached or exceeded the limits of its codes of record, NextEra would have to perform prompt operability determinations and come into compliance with its licensing basis or seek approval for a license amendment.[1145] For the prompt operability determination, NextEra would be obligated to demonstrate that the structures were operable, even if degraded.[1146]

4. Findings of Fact and Board Analysis

A contentious issue at the hearing concerned whether cracking of the concrete at Seabrook Unit 1 could be worse internally than it appears on the surface. If more serious internal cracking were the case, an unforeseen delamination of the concrete could result in structural failure. Thus, the concern is that internal microcracking and delamination could be degrading Seabrook's concrete, unnoticed by the current SMP monitoring protocol.

The FHWA Report states "concrete expansion [due to ASR] can also result in steel yielding, loss of concrete/steel bond, concrete delamination, with potential weakening of the structural integrity of the concrete member or structure."[1147] Thus, the FHWA Report acknowledges the potential for ASR-degradation leading to concrete delamination. The report further explains that the structural assessment of an ASR-affected structure must focus on a

[1143] Tr. at 1057 (Thomas).

[1144] Tr. at 392 (Collins).

[1145] See Tr. at 719–20 (Buford, Lehman), 739–42 (Buford), 1012 (Buford).

[1146] Tr. at 948–49 (Buford).

[1147] See Ex. NER013, FHWA Report at 35.

number of aspects, including concrete delamination.[1148] Then, "[t]he decision should be made concerning the application of appropriate remedial measures . . . ."[1149] The ISE document also states that "where there is no [through-thickness] reinforcement there is now more evidence of delamination . . . developing with 'Severe' [ASR]."[1150]

The Board must determine, based upon the preponderance of the evidence, whether NextEra has established its position that the possibility of delamination of the concrete at Seabrook is sufficiently understood and monitored such that the continued operation of Seabrook will not "endanger[] the health and safety of the public."[1151]

The Board notes that C-10 initially argued that the "edge effect" crack observed in LSTP specimens was indicative of delamination and thus rendered the LSTP test specimens unreliable and not representative of conditions at Seabrook.[1152] Subsequently, C-10 stated that delamination may indeed occur at Seabrook, and thus the LSTP mid-plane crack is representative.[1153] The majority of C-10's arguments concerned the possibility of delamination at Seabrook. Thus, the Board assesses C-10's testimony according to the latter view.

As part of its SMP monitoring protocol, NextEra removes concrete cores from Seabrook at the locations where it has installed extensometers.[1154] The cores and corresponding boreholes are then subjected to visual examination to confirm the absence of mid-plane

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[1148] Id.

[1149] Id.

[1150] See Ex. NER012, ISE Structural Effects of [ASR] Addendum at 3 of 5 (non-public).

[1151] 10 C.F.R. § 50.57(a)(3).

[1152] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 15–17 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 15–17; C-10 Opp. to MIL 2 at 14.

[1153] Ex. INT028, Dr. Saouma Rebuttal Testimony at 28–29 (non-public); Ex INT032, Dr. Saouma Rebuttal Testimony at 28–29; Tr. at 707 (Saouma).

[1154] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 3-1.5 (non-public).

cracks.[1155] Thus, NextEra conceded that it is concerned about the potential for mid-plane cracking that could possibly lead to delamination.[1156] However, an LSTP conclusion that guides the SMP is that there is no internal ASR-induced cracking that is worse than cracking that is visible on the surface.[1157] The Staff concurred with this view and stated "[e]xpansion of any significance will manifest on the surface in the form of cracking, spalling, pop-outs, relative displacements, or deformation long before any [impact to structural performance]."[1158]

NextEra used the CI measurements at Seabrook to implement thermal loads in its FEA.[1159] Since the measured CI values in the horizontal and vertical directions were different, anisotropy was implemented for those directions;[1160] however, NextEra did not implement such a procedure for the through-thickness direction, arguing that their use of shell elements in the FEA rendered it unnecessary.[1161] Given the uncertainties in NextEra's approach and the potential severity—catastrophic failure—of a delamination event, NextEra has not persuaded us that it is properly accounting for the possibility of delamination. Indeed, given the example of the unforeseen delamination and subsequent significant structural damage at the Crystal River nuclear plant,[1162] albeit for non-ASR reasons, delamination is an issue that cannot be ignored. NextEra and Staff statements that they have not seen delamination in any of the 200 core

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[1155] Id. (non-public); Ex. NER020, MPR 0326-0062-88, Rev. 2 at 4 (non-public); Tr. at 455–56 (Sherman), 572 (Carley), 704–05 (Bayrak), 710–11 (Carley), 1096–98 (Bayrak).

[1156] Tr. at 710–11 (Carley), 1097–98 (Bayrak).

[1157] Tr. at 358 (Bayrak).

[1158] Ex. NRC001-R, Staff Testimony at 64.

[1159] Ex. NER004, SGH Testimony at 40–41, 66; see Ex. INT022, SEM at PDF 18–24.

[1160] Ex. INT015, SGH Evaluation and Design Confirmation of As-Deformed CEB at 93 tbl.13 (showing the separate "hoop" (i.e., horizontal) and "meridional" (i.e., vertical) CI measurements used in the FEA).

[1161] Ex. NER004, SGH Testimony at 63–64, 66; Tr. at 954, 1174 (Bolourchi).

[1162] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 16–17 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 16–17.

samples that they have examined fall short when compared to the potential severity of not catching an unseen problem. Indeed, microcracking cannot be seen with the naked eye, but must be observed by another method, such as petrography,[1163] and NextEra testified that it did not perform petrographic examinations on all the cores that it extracted from Seabrook.[1164]

In other words, since the SMP is based upon the paradigm that internal cracking is first evidenced by surface cracking as measured by various cracking indices,[1165] any phenomenon without surface cracking will escape detection. The Board finds that NextEra does not have an adequate screening procedure to detect internal cracking and delamination in Seabrook's concrete.

The further complicating issue of localized excursions of Seabrook structures outside the linear elastic regime is a serious concern. Since the failure mode associated with combined ASR degradation and an earthquake is a brittle, shear failure without ample warning of its occurrence,[1166] the Board is concerned about the potential for sudden significant, localized damage due to shear failure, given that all parties agreed that there may be localized excursions of Seabrook Unit 1 into the nonlinear structure plastification regime. The Staff is confident that it can handle oversight of NextEra's response to such behavior, given its experience with applying the design code to localized nonlinearities at the other approximately 100 nuclear reactors in operation across the United States.[1167] However, those excursions at the other reactors do not involve the newly found phenomenon of reactor concrete degradation due to ASR.

[1163] Tr. at 1140 (Saouma).

[1164] Tr. at 532 (Carley) ("[I]n some cases, we do . . . petrographic examination. We have done it. We just don't do it on every single core.").

[1165] Ex. INT010, Original LAR at PDF 32 tbl.4; see supra Part VIII.A.2.

[1166] Tr. at 1058–59 (Saouma).

[1167] Tr. at 1055–56 (Thomas).

The Board notes the lack of experience in the other reactors around the country in addressing the possibility of ASR-induced localized excursions outside the linear elastic regime. The Board also is not persuaded that NextEra and the Staff have a sound plan in place to detect and address internal microcracking and the potential for an unforeseen delamination. Thus, the Board finds that NextEra has not shown, by a preponderance of the evidence, that there is reasonable assurance that the continued operation of Seabrook Unit 1 will not endanger the health and safety of the public with regard to this particular issue of delamination. However, these shortcomings of the LAR can be corrected. According to a Report of the Swiss Committee on Dams, "[ASR] generated micro-cracks and associated gel precipitations are easily recognizable under the light microscope" during the petrographic analysis of a core. Thus, the Board finds that the petrographic analysis of each extracted core would gauge the degree of internal microcracking (possibly resulting in macrocracking) that could lead to catastrophic delamination.

Therefore, the Board imposes the following license condition:

Each core extracted from Seabrook Unit 1 will be subjected to a petrographic analysis to detect internal microcracking and delamination.

Finally, both C-10 and NextEra agreed that crack index monitoring is an initial monitoring technique to be applied to ASR-degraded concrete.[1168] As for a more thorough analysis, the Board notes that the above license condition is consistent with the FHWA Report that states "[t]he quantitative assessment of the extent of cracking through the [c]racking [i]ndex, along with the [p]etrographic [e]xamination of the cores taken from the same affected element, [are] used as tools for the early detection of ASR in the concrete."[1169]

[1168] Tr. at 494 (Saouma), 510–11 (Simons).

[1169] See NER013, FHWA Report at 3 (italics omitted).

F. C-10's Remaining Issues Are Outside the Scope of the Proceeding

1. Deformation Monitoring

Seabrook's Structures Monitoring Program (SMP), as relevant to the LAR, has two distinct parts—Expansion Monitoring, which involves collecting ASR expansion measurements from Seabrook structures for monitoring against specified acceptance criteria based on the LSTP; and Deformation Monitoring, which requires gathering in-situ data for monitoring against thresholds established in the structural evaluations.[1170] Deformation Monitoring in the SMP evaluates external loads and monitors their effects on structures using FEA considering ASR expansion and other effects such as creep, shrinkage, and swelling.[1171]

NextEra asserted that Dr. Saouma "raise[d] a host of new issues and challenges related to structural evaluations, the [SEM], [FEA], and [structural deformation monitoring . . . [that] could have been, but were not, raised at the outset of this proceeding."[1172] Moreover, NextEra asserted that testimony challenging the treatment of ASR expansion as a "design basis load" is new and entirely unrelated to the representativeness of the LSTP.[1173] Further, NextEra alleged it "developed the approach of calculating ASR loads and load factors independent of the

[1170] Ex. NER001, MPR Testimony at 59, 111–13; see Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 4-1.2 (non-public).

[1171] Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 4-1.1 to -1.3 (non-public); Ex. NER004, SGH Testimony at 16 ("Evaluations of structural adequacy are exercises to determine whether the 'demands' (i.e., load effects) on a structure or its elements exceed the 'capacities' (e.g., strength or stress limits) of the structure or its elements. Methods of determining appropriate demands and capacities are prescribed by specific criteria, standards, and codes. For Seabrook, these methods are described in its [Ex. NRC007,] UFSAR at Section 3.8.").

[1172] NextEra MIL 2 at 19.

[1173] Id. at 18. However, Dr. Saouma withdrew this argument at the hearing. Tr. at 440 (Saouma).

LSTP."[1174] NextEra maintained that none of those issues are sufficiently related to the "representativeness" of the LSTP to be considered within the scope of this proceeding.[1175]

C-10 argued that Dr. Saouma's arguments are properly before the Board.[1176] Furthermore, C-10 maintained that both the monitoring program for ASR progression and the monitoring program for structural deformation depend on the LSTP, and that both provide input to and assumptions for the FEA relied on by NextEra.[1177] Accordingly, C-10 asserted that NextEra incorrectly argued that the Deformation Monitoring Program and FEA have no relevance to the reformulated contention.[1178]

We emphasize that there is a distinction between the capacity and demand calculations used in the FEA, which is a component of Deformation Monitoring. We have held that the capacity side of the FEA (i.e., the assumption that capacity should be calculated using the code equations and the original material properties) is within the scope of this proceeding.[1179] However, we find the demand side analysis of the FEA, concerning the calculation of structural loads in addition to ASR loads, beyond the scope of the proceeding. Therefore, NextEra's Motion in Limine, as it pertains to FEA and Deformation Monitoring, is granted in part, and denied in part.

No quantitative data from the LSTP was used as a direct input into the FEA.[1180] We therefore conclude that the demand side equations of the FEA are beyond the scope of this

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[1174] NextEra MIL 2 at 18 (citing Ex. NER004, SGH Testimony at 17–18).

[1175] Id. at 18–20.

[1176] See generally C-10 Opp. to MIL 2.

[1177] Id. at 14–19.

[1178] Id. at 15.

[1179] See supra Part VIII.A.5.a.

[1180] Ex. NER004, SGH Testimony at 17–18 ("No specific measurements, calculations, data, or other information from the LSTP are direct inputs into the SEM or structural evaluations; and

proceeding. The ASR loads developed for each ASR-affected structure at Seabrook are estimated based on in-situ data, using CCI and other measurements, from Seabrook structures, unrelated to the LSTP.[1181] SGH developed the approach of calculating ASR loads and load factors independent of the LSTP.[1182] The use of CCI, as relevant to determining ASR loads in the FEA, is similarly beyond the proceeding's scope.[1183] "The only overlap of the structure[al] deformation monitoring program with the LSTP is that its use of code-based structural capacity acceptance criteria is tied to the point at which a structure would meet the expansion limits identified in the LSTP."[1184] Therefore, we agree with NextEra and hold the demand side equations of the FEA, concerning design basis loads and load factors, are independent of the LSTP and beyond the scope of this proceeding. We grant the Motion in Limine as to section C.2.4.3 of Dr. Saouma's pre-filed testimony, as well as section D.9.2 of Dr. Saouma's rebuttal testimony,[1185] because they are outside the scope of the reformulated contention and the Board's reformulated contention.[1186]

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nothing from the LSTP informed any baseline assumptions on the demand side of the equations for the SEM or the structural evaluations."); Ex. NRC001-R, Staff Testimony at 21–23.

[1181] Ex. NRC001-R, Staff Testimony at 21 ("[T]he ASR load developed in this manner with respect to each ASR-affected structure at Seabrook is estimated based on field data from the actual structures and is not derived from the LSTP."); Tr. at 901 (Bolourchi) ("[T]he amount of the expansion you simulate . . . comes from CCI measured in the field[.]").

[1182] Ex. NER004, SGH Testimony at 17–18.

[1183] Our earlier analysis which addressed CCI did so in the context of the LSTP, whereas here, CCI is used to gather in-situ data from the plant to inform the demand side of the FEA, which is beyond the scope of this proceeding. See supra Parts VIII.A.1–A.2.

[1184] Ex. NRC001-R, Staff Testimony at 22.

[1185] Ex. INT027, Dr. Saouma Pre-Filed Testimony § C.2.4.3; Ex. INT032, Dr. Saouma Rebuttal Testimony § D.9.2.

[1186] We need not rule on the appropriateness of Ex. INT027 § C.2.4.2, in which C-10 argued that NextEra confuses capacity and demand because Dr. Saouma withdrew the argument during the hearing. See Tr. at 440 (Saouma).

Insofar as Dr. Saouma presented additional challenges to the FEA, we find they are all beyond the scope as part of the demand side analysis.[1187] To be clear, the only aspect of the FEA we are considering is the use of the original code capacities. Since we already discussed the use of the original code capacities, supra Part VIII.A.5, there is nothing remaining to resolve regarding this matter.

2. Inadequate Peer Review

NextEra argued C-10's testimony regarding a lack of peer review should be excluded from the record for three reasons.[1188] First, the argument is "new" and was not mentioned in the Petition. Second, and alternatively, if the argument is not new, it is included within the subject of testimony found inadmissible as part of Contention E.[1189] Third, peer review is unrelated to representativeness.[1190] For its part, C-10 argued NextEra's failure to conduct peer review "is relevant to the adequacy of the [LSTP] and the monitoring program[.]"[1191] We agree with NextEra and exclude Dr. Saouma's testimony related to peer review from the record.

All parties offered arguments as to whether NextEra and the Staff obtained adequate peer review of the LAR, and whether peer review is necessary.[1192] Peer review might have

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[1187] Ex. INT001-R, Dr. Saouma Pre-Filed Testimony at 23–29 (non-public); Ex. INT027, Dr. Saouma Pre-Filed Testimony at 23–29; Ex. INT032, Dr. Saouma Rebuttal Testimony at 42; Ex. INT007, Dr. Saouma Review of Selected Documents at 9–19 (non-public); Ex. INT031, Dr. Saouma Review of Selected Documents at 10–19.

[1188] NextEra MIL 2 at 14–15.

[1189] Id. at 14–15, 14 n.58. "Contention E challenge[d] NextEra's use of proprietary information drawn from the [LSTP] in the LAR, arguing that the use of such information is 'not good science,' 'creates an air of secrecy that prevents review, and undermines . . . trust within the nearby communities[.]'" LBP-17-7, 86 NRC at 131 (quoting C-10 Petition at 11).

[1190] NextEra MIL 2 at 14–15.

[1191] C-10 Opp. to MIL 2 at 11; see also Ex. INT027, Dr. Saouma Pre-Filed Testimony at 36.

[1192] C-10 Opp. to MIL 2 at 11 ("[N]either NextEra nor the NRC Staff had followed the standard scientific method of obtaining an independent peer review of their work."); NextEra MIL 2 at 14 n.59 ("[I]f C-10 had raised this issue [of peer review] at the outset, it would have been rejected as immaterial (because there is no requirement for 'peer review' in 10 C.F.R. Part 50) and as demonstrably unsupported [throughout the record.]"); see NRC Staff's Proposed Findings of Fact and Conclusions of Law at 36–40.

allowed the scientific and engineering community to provide input to improve the LSTP. However, a lack of peer review is not a specific issue with a component of the LSTP, such as specimen size or concrete mineralogy. Peer review, by itself, is not a representativeness issue. It therefore does not fall within the scope of the reformulated contention, Contention D as a basis of that reformulated contention, or any of the other admitted contentions that comprise the bases of the reformulated contention. Because the testimony advocating peer review challenged the processes of establishing the LSTP and drafting the LAR but did not challenge a specific component of the LSTP for a lack of representativeness, we grant NextEra's Motion in Limine and will not consider the peer review issue further.

The Board also notes that NRC regulations in 10 C.F.R. Part 50 do not require that a license amendment request, or any analysis that supports such request, be submitted for peer review.[1193] Thus, had this issue been alleged in the C-10 Petition, it likely would not have been admitted because it would not have been material to the Staff's decision in reviewing the LAR.[1194]

We therefore grant NextEra's Motion in Limine regarding peer review.

3. Steel Corrosion

NextEra moved to exclude C-10's testimony on the subject of steel corrosion.[1195] Specifically, NextEra argued that the Board found the topic of steel corrosion was beyond the

[1193] See Ex. NRC001-R, Staff Testimony at 73–74; NextEra MIL 2 at 14 n.59.

[1194] The Board notes that the phrase "peer review" was mentioned in C-10's Petition, however it was stated in a passing manner and did not equate to an argument alleging a lack of peer review. In fact, the reference to peer review was made in the context of proposed Contention E, which we found wholly inadmissible. See C-10 Petition at 11 ("It is difficult to understand how withholding pertinent information, which would allow an independent assessment of the test results used to support the claims of NextEra, could reasonably be interpreted in this way. It is usual to actually submit such results for peer review to provide a basis for consensus among the relevant scientific community."); LBP-17-7, 86 NRC at 131–32; see also NextEra MIL 2 at 14 nn.58–59.

[1195] NextEra MIL 2 at 9.

scope of the proceeding in dismissing Contention F.[1196] Contention F stated "elevated levels of salt . . . [have] likely created the conditions for corrosion of reinforcing steel[.]"[1197] NextEra argued that Dr. Saouma's statement that testing for free chloride concentrations is important to "make sure that it is below critical limits before steel [depassivates] (i.e. corrode)"[1198] is "simply reiterat[ing] the argument previously rejected by the Board" in Contention F.[1199]

C-10, however, argued that Contention F challenged the monitoring of the rebar, whereas here, Dr. Saouma's argument for testing the concentration of free chloride is focused on monitoring concrete.[1200] Further, C-10 argued that testing for the free chloride concentration is included within the admissible purpose of determining "the required comprehensive petrographic analysis of in-situ concrete[.]"[1201] We agree with NextEra and exclude the testimony of steel corrosion.[1202]

C-10 failed to base its steel corrosion argument on a deficiency in the LAR and instead asserted that an alternative methodology should be implemented. In addition, C-10's attempt to distinguish the present testimony from that proffered in support of Contention F is unpersuasive. At its core, both arguments, although stated differently, are concerned with the corrosion of steel rebar. Dr. Saouma advocated for the testing of the free chloride concentration for one

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[1196] Id.; see LBP-17-7, 86 NRC at 132–33.

[1197] C-10 Petition at 12.

[1198] Ex. INT027, Dr. Saouma Pre-Filed Testimony at 22 ("Because of the proximity of the sea, concrete should be tested for its (free) chloride concentration and make sure that it is below critical limits before steel [depassivates] (i.e. corrode)."); Ex. INT032, Dr. Saouma Rebuttal Testimony at 36 ("[S]aline solution could easily find its way through the ASR-induced cracks, depassivating the steel rebar (according to Faraday's law), and causing corrosion (Hansen and Saouma, 1999)[.]").

[1199] NextEra MIL 2 at 9.

[1200] C-10 Opp. to MIL 2 at 5–6.

[1201] Id. at 6 (quoting LBP-17-7, 86 NRC at 112).

[1202] See supra note 1198.

purpose—to make sure it will not cause corrosion of the rebar.[1203] That is the exact subject we found inadmissible in Contention F.[1204] Further, as noted in our ruling on contention admissibility, the SMP contains a separate program for monitoring rebar that was not revised in the LAR.[1205] Therefore, for the aforementioned reasons, we grant NextEra's Motion in Limine to exclude testimony on the topic of testing for chloride concentration.

G. Unaddressed Issues

We reviewed the voluminous record associated with this proceeding and weighed the evidence presented and the parties' positions. The above discussions capture all of the material issues within the scope of the proceeding. To the extent we did not address an argument raised by C-10, we found it immaterial to the findings we must make.

IX. Conclusion

A. Summary of Board Holdings and License Conditions

The Board finds that the following conditions are necessary for the NextEra requested license amendment to satisfy regulatory requirements and so these conditions are added to License No. NPF-86, Amendment No. 159, Appendix C:

c. NextEra shall undertake the monitoring required by MPR-4273, Appendix B, Check 3, for control extensometers every six months, rather than in 2025 and every ten years thereafter.

[1203] The salt-induced corrosion of rebar, which is beyond the scope of the reformulated contention, is distinct from the ASR-induced cracking of rebar, which was addressed earlier, supra Part VIII.A.5; see Ex. INT027, Dr. Saouma Pre-Filed Testimony at 22 ("Because of the proximity of the sea, concrete should be tested for its (free) chloride concentration and make sure that it is below critical limits before steel [depassivates] (i.e. corrode).").

[1204] LBP-17-7, 86 NRC at 132–33.

[1205] Id. at 133 ("The plant's rebar is already subject to a monitoring program that is not being altered in this LAR"); see Ex. NER007, Seabrook [SMP] Manual Rev. 7 at 1-1.2, 2-1.1 (non-public).

d. If stress analyses conducted pursuant to the SEM show that the stress in the rebar from ASR-induced expansion and other loads will exceed the yield strength of the rebar, NextEra must develop a monitoring program sufficient to ensure that rebar failure or yielding does not occur, or is detected if it has already occurred, in the areas at-risk of rebar failure or yielding.

e. If the ASR expansion rate in any area of a Seabrook seismic Category I structure significantly exceeds 0.2 mm/m (0.02%) through-thickness expansion per year, NextEra's Management will perform an engineering evaluation focused on the continued suitability of the six-month monitoring interval for Tier 3 areas. If the engineering evaluation concludes that more frequent monitoring is necessary, it shall be implemented under the SMP.

f. Each core extracted from Seabrook Unit 1 will be subjected to a petrographic analysis to detect internal microcracking and delamination.

Subject to the listed conditions, the Board resolves the reformulated contention in favor of NextEra. With the addition of these necessary conditions to License Amendment No. 159, the Board concurs with the Staff that NextEra's proposed method to evaluate seismic Category I structures affected by ASR "is acceptable and provides reasonable assurance that these structures [will] continue to meet the relevant requirements of 10 [C.F.R.] Part 50, Appendix A, GDC 1, 2, 4, 16 (containment only) and 50 (containment only) and 10 [C.F.R.] Part 50, Appendix B."[1206]

B. Review of the Board's Decision

In accordance with 10 C.F.R. §§ 2.1210, 2.1212, and 2.341, this initial decision will constitute a final decision of the Commission 120 days after its issuance unless: (1) a party files

[1206] Ex. INT024, Final SE at PDF 69.

a petition for Commission review within twenty-five (25) days after service of this initial decision; or (2) the Commission directs otherwise. Within twenty-five (25) days after service of a petition for Commission review, parties to the proceeding may file an answer supporting or opposing Commission review. "Unless otherwise authorized by law, a party to an NRC proceeding must file a petition for Commission review before seeking judicial review of an agency action."[1207]

IT IS SO ORDERED.

THE ATOMIC SAFETY
AND LICENSING BOARD

/RA/

Ronald M. Spritzer, Chairman
ADMINISTRATIVE JUDGE

/RA/

Nicholas G. Trikouros
ADMINISTRATIVE JUDGE

/RA/

Dr. Sekazi K. Mtingwa
ADMINISTRATIVE JUDGE

Rockville, Maryland
August 21, 2020

[1207] 10 C.F.R. § 2.1212.

APPENDIX

GLOSSARY OF TERMS[1208]

Aggregate Particulate material, commonly gravel and sand, that is mixed with cement and water to produce concrete. Aggregate sizes can be coarse (large) or fine (small), with concrete mixture designs using a spectrum of aggregate sizes.

Alkali-Silica Reaction (ASR) A chemical reaction that can occur in concrete and produce an expansive gel that results in cracking and may eventually cause structural distress.

Axial compression Forces that compress (i.e., squeeze) a structural element together. Excessive axial compression loading will cause the element to crush.

Beam (one-way) shear Shearing forces are unaligned forces that push one part of the element in one direction and another part of the element in another direction. Forces applied in parallel planes that are some distance apart create compression and tension fields. Excessive one-way shear produces a diagonal failure plane between the unaligned, opposite forces.

Capacity Ability of a structural member to withstand applied load.

Chemical Prestressing In the context of ASR, "chemical prestressing" is a means for producing continuous compressive stress in reinforced concrete by virtue of ASR expansion being restrained by embedded reinforcement.

Compression A load applied to a structural member that is in the direction of pushing the constituents together; i.e., crushing. In other words, a compression load works to reduce the size of the component.

Prestressed Concrete A special form of reinforced concrete in which reinforcing steel (i.e., prestressing steel) is

[1208] See Ex. NER002, MPR Glossary at 1–4.

	tensioned against the concrete (putting concrete in compression.) The application of compression load to a concrete member improves its service performance by limiting tensile stresses or cracking resulting from those tensile stresses. The compressive stress from prestressing (i.e., precompression) must be completely overcome before the concrete member will be exposed to net tensile stress.
Combined Cracking Index (CCI)	A term used at Seabrook Station for a combination of Cracking Index values in both the horizontal and vertical directions.
Cracking Index (CI)	A crack width summation technique for quantitatively estimating tensile strains experienced by a reinforced concrete element. The Cracking Index is the ratio of the sum of crack widths to the length of which the crack summation activity is performed (i.e. the gauge length.)
Crack Width Summation	A technique for estimating expansion of a reinforced concrete element by measuring the widths of cracks along a line (or lines) of defined length.
Damage Rating Index (DRI)	A technique for characterizing ASR progression during petrographic examination by assigning a quantitative score to characterize certain features associated with ASR. The cumulative result is the DRI.
Demand	Potential load(s) that could be applied to a structural member.
Extensometer	A device for monitoring expansion into the depth of a concrete member that is embedded in a borehole drilled into concrete.
Finite Element Analysis (FEA)	The FEA is a computational model that includes various elements to collectively simulate the structural geometry, stiffness, and mass of the desired structure. Modelers can add loads (i.e., demands), such as gravity, wind, or ASR, to the FEA to measure structural responses.

Flexure	A force that causes a structural element to bend. Compression is applied on the inside radius of the bent member and tension is applied on the outside radius. For a concrete member, which is typically weaker in tension, excessive flexure loading will cause the element to split or tear on the tension side.
In-Plane Expansion	Expansion that occurs in the two dimensions of a concrete member that are visibly accessible at the surface. At Seabrook Station and in the LSTP test specimens, the "in-plane" directions are also parallel to the embedded reinforcement mats.
Limit state	A behavioral mode by which a structural response is examined. In structural design, each limit state must be evaluated to confirm structural adequacy. For example, a reinforced concrete component must be sufficiently strong in flexure, shear, etc.
Normalized Elastic Modulus	The ratio of the modulus of elasticity of ASR-affected concrete to the original elastic modulus. This parameter is the input variable for the correlation to determine through-thickness expansion prior to instrument installation.
Plain concrete	Concrete without reinforcing bars, or unreinforced concrete.
Petrographic evaluation	Microscopic examination of prepared concrete surfaces by a qualified petrographer. The examination assesses the overall quality of concrete and can determine causes for concrete degradation.
Punching (two-way) shear	For punching shear, force is applied locally, rather than in a uniform plane. In other words, a punching shear condition exists when a structural wall or a reinforced concrete slab is patch-loaded. An excessively patch-loaded area will result in critical levels of shear stresses and will eventually puncture the structural element in the vicinity of the patch-loaded area.
Reinforcement anchorage	The bond between the concrete to the embedded reinforcement that allows load to

	transfer from the concrete to the reinforcing bars. A loss of reinforcement anchorage would cause the reinforcing bars to "slip" within the concrete element. For reinforced concrete elements to behave in a manner consistent with the design principles, all reinforcement needs to be anchored.
Reinforcing bars (Rebar or Rebars)	Steel bars embedded in concrete to increase the capacity of the structural members to withstand design loads. Since concrete is strong in compression and weak in tension, the primary use of reinforcing bars is to reinforce the "tension side" of reinforced concrete elements.
Reinforcement ratio	The cross-sectional area of reinforcing bars divided by the entire cross section of the reinforced concrete structural member. This calculation determines the fraction of a reinforced concrete section occupied by reinforcement.
Representativeness	The ability to apply conclusions from one application to inform circumstances in another application. In the context of the admitted contention, "representativeness" refers to the results from the LSTP and their applicability to reinforced concrete structures at Seabrook Station.
Seismic Category I Structures	Structures at a nuclear power plant that must fulfill their design function following a design basis seismic event.
Shear	A loading condition where unaligned forces push one part of a structural member in one direction and another part of the member in another direction, creating a diagonal compression and tension field. Excessive shear forces produce a diagonal failure plane that runs between the applied load and a support reaction in a typical shear test.
Tension	A load applied to a structural member that is in the direction of pulling the constituents apart. In other words, a tensile load works to elongate, or increase the size of, a structural component.

Through-thickness expansion	Expansion that occurs in the dimension of a concrete member that is not visibly accessible at the surface, i.e., expansion in the direction through the surface. At Seabrook Station and in the LSTP test specimens, the through-thickness direction is not reinforced (except for the lower portion of the Containment structure).

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
NEXTERA ENERGY SEABROOK, LLC	)	Docket No. 50-443-LA-2
(Seabrook Station, Unit 1)	)	
	)	
(License Amendment)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of the foregoing **INITIAL DECISION (Ruling on the Reformulated Contention) (LBP-20-09)**have been served upon the following persons by Electronic Information Exchange.

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Office of the Secretary of the Commission

Dated at Rockville, Maryland,
this 10th day of September 2020.