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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
E. Roy Hawkens, Chair
Dr. Paul B. Abramson
Dr. Anthony J. Baratta

In the Matter of:	)	October 10, 2007
AmerGen Energy Company, LLC	)	
	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

AMERGEN'S PROPOSED
<u>FINDINGS OF FACT AND CONCLUSIONS OF LAW</u>

Pursuant 10 C.F.R. § 2.1209 and the Atomic Safety and Licensing Board's ("Board") Memorandum and Order (Prehearing Conference Call Summary, Case Management Directives, and Final Scheduling Order) dated April 17, 2007, Applicant AmerGen Energy Company, LLC ("AmerGen") hereby submits its proposed findings of fact and conclusions of law in the above-captioned proceeding. At issue is a single contention related to AmerGen's aging management program for the primary containment drywell shell. These proposed findings support the Board's determination, under 10 C.F.R. §§ 54.21 and 54.29, that a renewed license should be issued authorizing AmerGen to operate the Oyster Creek Nuclear Generating Station ("OCNGS") for an additional 20-year term. The proposed findings of fact and conclusions of law are submitted in the form of a proposed Initial Decision by the Board.

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As described in detail below, the Board concludes that AmerGen's scheduled ultrasonic testing ("UT") frequency in the sand bed region of the drywell shell is adequate. First, AmerGen has arrested the corrosion of the external surface of the drywell shell sand bed region by removing the sand, eliminating the source of water leakage that historically caused the corrosion, and applying a multi-layer epoxy coating system. Even if water were to reach the external sand bed region, AmerGen's monitoring commitments would detect the water and AmerGen would initiate corrective actions. Even if the coating were to fail and water were to reach the external sand bed region undetected, corrosion would be most likely to occur near the floor of the former sand bed, where the available margin for drywell shell thickness is over 0.200". In this event, expected corrosion rates would be approximately 0.003" per year, so AmerGen's four year interval between UT inspections is more than adequate. Finally, significant corrosion of the sand bed region drywell shell from the interior is not expected because the shell there is embedded in concrete. The concrete will cause any water to become basic (*i.e.*, high pH) and, therefore, non-corrosive. There are, therefore, multiple reasons why AmerGen's scheduled UT frequency is adequate.

I. INTRODUCTION

1.1 This Initial Decision addresses AmerGen's license renewal application for OCNGS filed on July 22, 2005, and the single contention, proffered by Citizens,[1] that AmerGen's scheduled ultrasonic testing ("UT") frequency for assessing the thickness of the sand bed region of the OCNGS drywell shell is insufficient to maintain an adequate safety margin during the period of extended operation under the proposed renewed license.

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1. "Citizens" are: Nuclear Information and Resource Service; Jersey Shore Nuclear Watch, Inc.; Grandmothers, Mothers and More for Energy Safety; New Jersey Public Interest Research Group; New Jersey Sierra Club; and New Jersey Environmental Federation. In certain orders early in this proceeding, this Board referred to all six organizations collectively as "NIRS." For clarity, in this Initial Decision we refer to all six groups as "Citizens."

1.2 Based on the pre-filed testimony and exhibits submitted by the parties, and the testimony provided during the evidentiary hearing held in Toms River, New Jersey on September 24 and 25, 2007, and for the reasons set forth below, the Board concludes that AmerGen's scheduled UT frequency is adequate to ensure the actual thickness of the sand bed region of the OCNGS drywell shell remains above the applicable acceptance criteria and that there is reasonable assurance that the drywell shell will be maintained consistent with the OCNGS current licensing basis ("CLB") for the period of extended operation, subject to the additional license condition identified in Finding 4.20, below.

1.3 Section II below summarizes the procedural history of this proceeding. Section III sets forth the applicable legal standards. Section IV provides findings regarding background on the sand bed region of the drywell shell and the historical corrosion that occurred in that region. Section V provides findings regarding the applicable drywell shell thickness acceptance criteria. Section VI provides findings on the current available "margin" between the actual drywell shell thickness in the sand bed region and the applicable acceptance criteria. Section VII provides findings regarding the known sources of water or moisture that could leak onto the drywell shell and cause further corrosion, and AmerGen's efforts to prevent such leakage from occurring. Section VIII provides findings regarding the three-layer epoxy coating on the exterior surface of the drywell shell in the sand bed region and the extent to which it can be expected to prevent future corrosion, even if water or moisture are present at some time during the period of extended operation. Section IX addresses future rates of corrosion in order to assess whether AmerGen's scheduled UT frequency is adequate to detect such corrosion, should it occur, before the applicable acceptance criteria were exceeded. In Section X, the Board presents its conclusions of law that the periodicity of UT measurements is adequate to ensure that the intended function of the drywell shell will be maintained consistent with the CLB during the period of extended operation. Finally, in Section XI, the Board sets forth its Order.

II. PROCEDURAL HISTORY

2.1 On July 22, 2005, AmerGen filed its license renewal application ("LRA") for OCNGS.[2] Consistent with 10 C.F.R. § 54.17(c), the LRA seeks to extend the current operating license for the facility, which expires on April 9, 2009, for an additional twenty years.[3] On September 15, 2005, the NRC published a notice of opportunity for hearing in the *Federal Register*, notifying any person whose interest might be affected by the proceeding of the opportunity to request a hearing and file a petition for leave to intervene.[4]

2.2 On November 14, 2005, the State of New Jersey, Department of Environmental Protection ("NJDEP") filed a Request for Hearing and Petition for Leave to Intervene. In its Petition, the NJDEP proffered three contentions challenging: (1) AmerGen's analysis of Severe Accident Management Alternatives ("SAMA") under 10 CFR § 51.53(c) ("NEPA-terrorism contention"); (2) its compliance with the American Society of Mechanical Engineers ("ASME") Code with respect to metal fatigue; and (3) reliance on the Forked River Combustion Turbines as a standby source of electrical power pursuant to an interconnection agreement with another electric utility.[5]

2.3 On the same day that the NJDEP proffered its contentions, Citizens also filed a request for hearing and petition to intervene.[6] Citizens' Original Petition proffered a single contention challenging whether AmerGen's drywell liner corrosion management program

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2 *See* 70 Fed. Reg. 54,585 (Sept. 15, 2005).

3 *Id.*

4 *Id.*

5 NJDEP Request for Hearing and Petition for Leave to Intervene (Nov. 14, 2005).

6 NIRS et al. Request for Hearing and Petition to Intervene (Nov. 14, 2005) ("Original Petition").

provided reasonable assurance that the drywell had enough margin to meet applicable ASME Code criteria during the period of extended operation. *Id.*

2.4 On December 9, 2005, this Board was established to preside over the OCNGS license renewal proceeding.[7]

2.5 AmerGen and the U.S. Nuclear Regulatory Commission ("NRC") Staff ("Staff") opposed admission of all contentions as lacking in basis, failing to identify a genuine dispute, falling outside the scope of the proceeding, or a combination of these reasons.[8]

2.6 On February 7, 2006, Citizens requested leave to file two new contentions, or, in the alternative, supplement the basis of the contention it had proffered in its Original Petition, alleging that the NRC Staff had divulged new information regarding the need for monitoring and analysis of corrosion problems.[9] This pleading requested that, if the Board found that corrosion of inaccessible areas was not part of the Original Petition, Citizens should be allowed to submit a new contention that the "monitoring regime for the inaccessible areas of the drywell liner was inadequate, and must at least include ongoing, regular, direct measurements of thickness at all areas where corrosion could have occurred for the life of the plant and clear acceptance criteria for the measurements."[10] Also, Citizens' proffered a new contention proposing that AmerGen be required "to conduct a root cause analysis of the corrosion problem and implement a verifiable

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7 Establishment of Atomic Safety and Licensing Board, ASLBP No. 06-844-01-LR (Dec. 9, 2005).

8 AmerGen' Answer Opposing NJDEP's Request for Hearing and Petition to Intervene (Dec. 12, 2005); AmerGen's Answer Opposing NIRS et Al. Request for Hearing and Petition to Intervene (Dec. 12, 2005); NRC Staff Answer to Request for Hearing and Petition to Intervene of the State of New Jersey Department of Environmental Protection (Dec. 12, 2005); NRC Staff Answer to Request for Hearing and Petition to Intervene (Dec. 14, 2005).

9 Motion for Leave to Add Contentions or Supplement the Basis of the Current Contention (Feb. 7, 2006).

10 *Id.* at 13.

program to eliminate leakage of water onto the drywell liner."[11] AmerGen and the Staff opposed admission of these new contentions.[12]

2.7 On February 27, 2006, the Board granted Citizens' request for hearing, finding that Citizens had standing and had submitted an admissible contention.[13] In granting Citizens' request, the Board narrowed the scope of the admitted contention to be litigated. The Board excluded, as lacking adequate basis, Citizens' allegations that AmerGen's aging management program ("AMP") for the upper drywell liner (*i.e.*, above the sand bed region) was deficient, because Citizens failed "to explain with specificity or support why AmerGen's corrosion management program for that region is inadequate."[14] The Board also excluded any allegations related to the scope of AmerGen's UT monitoring program in the sand bed region.[15] Finally, the Board excluded Citizens' attempt, in their December 19, 2005 Reply Brief, to add the embedded region of the drywell, below the sand bed region, to the scope of their contention.[16] Therefore, the admitted contention challenged only the lack of UT measurements in the sand bed region, because at that time, AmerGen's AMP for the drywell shell did not include UT measurements in the sand bed region during the period of extended operation:

> AmerGen's License Renewal Application fails to establish an adequate aging management plan for the sand bed region of the drywell liner, because its corrosion management program *fails to*

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[11] *Id.*

[12] AmerGen's Answer to Petitioners' Motion for Leave to Add Contentions or Supplement the Basis of the Current Contention (Feb. 17, 2006); NRC Staff's Response to Motion for Leave to Add Contentions or Supplement the Basis of the Current Contention (Feb. 17, 2006).

[13] Memorandum and Order (Denying New Jersey's Request for Hearing and Petition to Intervene, and Granting NIRS's Request for Hearing and Petition to Intervene), LBP-06-07, 63 N.R.C. 188 (2006).

[14] *Id.* at 217 n.27.

[15] *Id.* at 217 n.28. Following Citizens' Original Petition, AmerGen committed to a one-time set of confirmatory UT measurements in the sand bed region prior to the period of extended operation. Letter from C. N. Swenson, Site Vice President, OCNGS, to NRC Document Control Desk, re: Additional Commitments Associated with Application for Renewed Operating License – Oyster Creek Generating Station at 3 (Dec. 9, 2005).

[16] LBP-06-07, 63 N.R.C. at 217 n.28.

include periodic UT measurements in that region throughout the period of extended operation and, thus, will not enable AmerGen to determine the amount of corrosion in that region and thereby maintain the safety margins during the term of the extended license.[17]

2.8 The admission of this contention triggered the mandatory disclosure process under 10 C.F.R. § 2.336.

2.9 In its February 27, 2006 decision, the Board denied NJDEP's Request for Hearing and Petition for Leave to Intervene[18] finding that while NJDEP had established standing, it had failed to proffer an admissible contention.[19] NJDEP appealed our decision to the Commission.[20] On September 6, 2006, the Commission affirmed our decision denying admission of New Jersey's combustion turbine and metal fatigue contentions, and denied Citizens' request for reconsideration.[21] The Commission postponed its decision on NJDEP's appeal of our denial of its NEPA-terrorism contention[22] until February 26, 2007, when the Commission also affirmed our denial of that contention. It also held that pending appeals (filed by AmerGen and the NRC Staff seeking reversal of our decision to admit the original contention filed by Citizens) were moot because, as discussed below, the original contention had by then been dismissed and a new

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17 *Id.* at 217 (emphasis added).

18 *Id.* at 194.

19 *Id.*

20 *See* Brief on Behalf of Petitioner New Jersey Department of Environmental Protection on Appeal from Order LBP-06-07 of the Atomic Safety and Licensing Board Denying Request for Hearing and Petition to Intervene (Mar. 28, 2006).

21 *AmerGen Energy Company, LLC* (Oyster Creek Nuclear Generating Station), CLI-06-24, 64 N.R.C. 111 (2006).

22 This was due, *inter alia*, to the United States Supreme Court extending by 30 days the August 31, 2006 deadline for asking the Court to review *San Luis Obispo Mothers for Peace v. NRC*, 449 F.3d 1016 (9th Cir. 2006). CLI-06-24, 64 N.R.C. at 115.

contention admitted.[23] NJDEP appealed the Commission's NEPA-terrorism decision to the U.S. Court of Appeals for the Third Circuit. That appeal is not the subject of this Initial Decision.

2.10 On March 22, 2006, the Board found that both late-filed contentions proffered by Citizens on February 7, 2006 were incurably late and substantively inadmissible, because they were not based on information that was either new or materially different than what was previously available,[24] and because they "fail[ed] to identify an alleged deficiency that is specific to Oyster Creek or its License Renewal Application."[25]

2.11 On April 6, 2006, Citizens filed a motion for reconsideration of our decision on their February 7, 2006 late-filed contentions, averring that the Board: (1) misinterpreted the law regarding what constitutes new information under 10 CFR § 2.309(f)(2) for purposes of adding or amending contentions; (2) the Board failed to note a key fact (*i.e.*, that ongoing corrosion is occurring above the sand bed region); and (3) the Board erroneously ruled that Citizens' newly-presented contentions failed to satisfy the admissibility requirements of 10 CFR § 2.309(f)(1).[26] AmerGen and the Staff opposed Citizens' motion as failing to demonstrate the requisite compelling circumstances under 10 C.F.R. § 2.323(e).[27]

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23 *See AmerGen Energy Company, LLC* (License Renewal for Oyster Creek Nuclear Generating Station), Memorandum and Order, CLI-07-08, 65 N.R.C. 124 (Feb. 26, 2007).

24 Memorandum and Order (Denying NIRS's Motion for Leave to Add Contentions or Supplement the Basis of the Original Contention), LBP-06-11, 63 N.R.C. 391, 398, 400 (2006).

25 *Id.* at 401; *see also id.* at 398.

26 Motion for Reconsideration of Motion to Add New Contentions or Supplement the Basis of the Current Contention and Leave to File Such a Motion (Apr. 6, 2006).

27 AmerGen Brief Opposing Citizens' Notice of Appeal of LBP-06-11 (Apr. 17, 2007); NRC Staff Brief Opposing NIRS's Notice of Appeal of LBP-06-11 (Apr. 17, 2006).

2.12 Citizens also appealed the denial of their late-filed contentions to the Commission.[28] In doing so, Citizens relied on the same brief submitted in support of their February 7, 2006 Motion for Reconsideration.[29]

2.13 On March 28, 2006, the Board issued a Notice that a hearing would be conducted in this proceeding.[30] The notice stated that the hearing would be governed by the informal hearing procedures set forth in 10 CFR Part 2, Subpart L.[31] Following an April 10, 2006 pre-hearing conference call, the Board issued an Initial Scheduling Order on April 19, 2006.[32]

2.14 On April 25, AmerGen filed a motion to dismiss Citizens' sole contention on the basis of new commitments that AmerGen had docketed with the NRC to perform periodic UT monitoring of the sand bed region during the period of extended operation.[33] AmerGen argued that these new commitments rendered moot Citizens' contention, because the contention was one of omission that had been cured by AmerGen's submittal of commitments to perform periodic

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28 Citizens' Notice of Appeal of LBP-06-11 (Apr. 6, 2006).

29 NRC regulations do not allow such an appeal, and therefore the Commission declined to address the merits. CLI-06-24, 64 N.R.C. at 122.

30 Notice of Hearing (Application for 20-year License Renewal) (Mar. 28, 2006) (unpublished).

31 *Id.* at 2.

32 Memorandum and Order (Prehearing Conference Call Summary, Initial Scheduling Order, and Administrative Directives) (Apr. 19, 2006) (unpublished).

33 AmerGen's Motions to Dismiss Drywell Contention as Moot and to Suspend Mandatory Disclosures (Apr. 25, 2006). At the time that Citizens submitted their Original Petition, AmerGen's LRA contained no provisions for future UT measurements in the sand bed region of the drywell shell, based upon its conclusion that corrosion in that area has been arrested, and that the planned, continued visual inspections of the multi-layered epoxy coating covering the drywell shell in the sand bed region would be adequate. *Id.* at 2. By letter dated December 9, 2005, however, AmerGen formally docketed a commitment to perform a one-time UT examination of the sand bed region prior to the period of extended operation under the renewed license. *Id.* On April 4, 2006 AmerGen docketed a further commitment to perform additional UT examinations in the sand bed region of the drywell once every ten years during the period of extended operation. *Id.* at 2-3.

UT examinations during the period of extended operation.[34] The Staff supported AmerGen's Motion,[35] but Citizens opposed it.[36]

2.15 On April 27, 2006, the Board issued a Memorandum and Order denying Citizens' Motion for Reconsideration of its March 22, 2006 denial of Citizens' February 7, 2006 motion to add new contentions. The Board found that motion without merit because it failed to demonstrate compelling circumstances that would justify reconsideration.[37]

2.16 Citizens then filed two motions on May 5, 2006: a Motion to Apply Subpart G Procedures (alleging misconduct and a general lack of trustworthiness on the part of AmerGen and its parent company, Exelon); and a Motion to Compel Further Mandatory Disclosures (seeking disclosure of records relating to corrosion above the sand bed region).[38] Citizens' Motion for Subpart G procedures alleged that there were credibility issues with AmerGen's statements that warranted use of formal hearing procedures. AmerGen opposed both motions.[39] The Staff opposed the Motion to Apply Subpart G Procedures, but did not respond to the Motion to Compel.[40]

2.17 On June 5, 2006, the Board denied Citizens' Motion to Apply Subpart G Procedures,[41] basing its decision on: (1) Citizens' failure to show that the *alleged* misconduct by

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[34] *Id.* at 3-4.

[35] NRC Staff's Response to AmerGen's Motion to Dismiss Drywell Contention as Moot (May 5, 2006).

[36] Citizens' Brief in Opposition to AmerGen's Motion to Dismiss and to Suspend Mandatory Disclosures (May 5, 2006).

[37] *See* Memorandum and Order (Denying NIRS's Motion for Reconsideration) (Apr. 27, 2006) (unpublished).

[38] Motion to Apply Subpart G Procedures (May 5, 2006); Motion to Compel Further Mandatory Disclosures (May 5, 2006).

[39] AmerGen's Answer Opposing Citizens' Motion to Apply Subpart G Procedures (May 16, 2006); AmerGen's Answer Opposing Citizens' Motion to Compel Further Mandatory Disclosures (May 16, 2006).

[40] *See* NRC Staff Response to Motion to Apply Subpart G Procedures (May 16, 2006); Letter from Mitzi Young, Counsel for NRC Staff, to Administrative Judges (May 16, 2006).

[41] Memorandum and Order (Denying NIRS's Motion to Apply Subpart G Procedures) (June 5, 2006) (unpublished).

Exelon employees at two other Exelon facilities was related to the "resolution of issues of material fact relating to the occurrence of a past activity" that had been placed in dispute by the contention in the OCNGS proceeding; (2) Citizens' failure to show that any of the individuals involved in the alleged events at the other facilities would likely be eyewitnesses whose credibility could reasonably be expected to be at issue in the OCNGS license renewal proceeding; (3) the fact that Exelon and AmerGen are two separate corporate entities; and (4) Citizens' allegations of misleading statements by AmerGen did not warrant the application of Subpart G procedures.[42]

2.18 On the next day, June 6, 2006, the Board issued a Memorandum and Order concluding that Citizens' sole admitted contention was moot and subject to dismissal.[43] Specifically, the Board found that Citizens' admitted contention was a contention of omission that had been cured by AmerGen's commitment to perform UT testing.[44] When a contention of omission that is the sole contention in a proceeding has been rendered moot and no other motions remain pending, an order dismissing the contention ordinarily would terminate the proceeding. The Board nonetheless refrained from issuing an order of dismissal for 20 days from the date of our decision. This provided Citizens the opportunity to file a new contention raising a specific substantive challenge to AmerGen's periodic UT program for the sand bed region.[45]

2.19 On June 23, 2006, Citizens proffered the following new contention:

> AmerGen must provide an aging management plan for the sand bed region of the drywell shell that ensures that safety margins are maintained throughout the term of any extended license, but the

[42] *Id.* at 4-6.

[43] Memorandum and Order (Contention of Omission is Moot, and Motions Concerning Mandatory Disclosures are Moot), LBP-06-16, 63 N.R.C. 737, 739 (2006). This Order also rendered Citizens' Motion to Compel Further Mandatory Disclosures to be moot. *Id.*

[44] *See id.* at 742-744.

[45] *Id.* at 744.

> proposed plan fails to do so because the acceptance criteria are inadequate, the monitoring frequency is too low and is not adaptive to possible future narrowing of the safety margins, the scope of the monitoring is insufficient to systematically identify and sufficiently test all the degraded areas of the shell in the sand bed region, the quality assurance for the measurements is inadequate, and the methods proposed to analyze the results are flawed.[46]

2.20 Along with their June 23 Petition, Citizens also filed a Motion for Leave to Supplement the Petition, based on additional commitments docketed by AmerGen on June 20, 2006. Citizens' Motion requested the opportunity to address AmerGen's new commitments and the new information provided in AmerGen's June 20, 2006 letter.[47]

2.21 On July 5, 2006, the Board granted Citizens' Motion for Leave to Submit a Supplement to its Petition, but strictly defined the scope of any supplement, however, requiring that it be limited to AmerGen's UT program for the sand bed region as reflected in AmerGen's docketed commitment of June 20, 2006, and be based on new information contained in that commitment.[48] The Board further required that Citizens demonstrate that the supplement satisfies the applicable criteria of 10 CFR § 2.309(f)(2) as well as the contention admissibility requirements in 10 CFR § 2.309(f)(1).[49]

2.22 On July 25, 2006, Citizens filed their Supplement to Petition to Add a New Contention, challenging the adequacy of AmerGen's AMP for the drywell shell as modified by the June 20, 2006 commitments. The text of the proposed amended contention was:

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[46] Petition to Add a New Contention at 4 (June 23, 2006).

[47] Letter from Michael Gallagher, Vice President, License Renewal, AmerGen Energy Co., LLC, to NRC Document Control Desk, re: Supplemental Information Related to the Aging Management Program for the Oyster Creek Drywell Shell, Associated with AmerGen's License Renewal Application (TAC No. MC7624) (June 20, 2006).

[48] Order (Granting NIRS's Motion for Leave to Submit a Supplement to its Petition) (July 5, 2006) (unpublished).

[49] *Id.* at 3.

> AmerGen must provide an aging management plan for the sand bed region of the drywell shell that ensures that safety margins are maintained throughout the term of any extended license, but the proposed plan fails to do so because the acceptance criteria are inadequate, the scheduled UT monitoring frequency is too low in the absence of adequate monitoring for moisture and coating integrity and is not sufficiently adaptive to possible future narrowing of the safety margins, the monitoring for moisture and coating integrity is inadequate, the response to wet conditions and coating failure is inadequate, the scope of the UT monitoring is insufficient to systematically identify and sufficiently test all the degraded areas of the shell in the sand bed region, the quality assurance for the measurements is inadequate, and the methods proposed to analyze the UT results are flawed.[50]

AmerGen opposed admission of Citizens' new contention.[51] The NRC Staff argued that the contention was admissible in part; *i.e.*, only to the extent it challenged the scheduled UT monitoring frequency in the sand bed region.[52]

2.23 On October 10, 2006, the Board admitted Citizens' new contention in part.[53] Significantly, in its Memorandum and Order, the Board identified seven discrete challenges in Citizens' Petition and Supplement:

1) AmerGen's acceptance criteria are inadequate to ensure adequate safety margins.

2) AmerGen's scheduled UT monitoring frequency in the sand bed region is insufficient to maintain an adequate safety margin.

3) AmerGen's monitoring in the sand bed region for moisture and coating integrity is inadequate.

4) AmerGen's response to wet conditions and coating failure in the sand bed region is inadequate.

5) AmerGen's scope of UT monitoring is insufficient to systematically identify and sufficiently test all the degraded areas in the sand bed region.

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50 Supplement to Petition to Add a New Contention at 7 (July 25, 2006) ("Citizens' Petition").

51 AmerGen's Answer to Citizens' Petition to Add a New Contention and Supplement Thereto (Aug. 11, 2006).

52 NRC Staff Answer to Petition to Add a New Contention and Petition Supplement at 12 (Aug. 21, 2006).

53 Memorandum and Order (Granting Petition to File a New Contention), LBP-06-22, 64 N.R.C. 229 (2006).

6) AmerGen's quality assurance for the measurements in the sand bed region is inadequate.

7) AmerGen's methods for analyzing UT results in the sand bed region are flawed.[54]

2.24 Among these seven challenges, the Board found that only challenge 2), above, constituted an admissible contention, and that the other six did not, because they were incurably late, lacking in basis, or both.[55] The Board reaffirmed its previous orders in this proceeding in that it ruled that the scope of Citizens' admitted contention is limited to the sand bed region, and thus issues related to the upper and embedded regions of the drywell remained outside the scope of the proceeding.[56] The Board also ruled that allegation 6), above, was an impermissible challenge to the OCNGS CLB.[57] Finally, the Board responded to Citizens' allegation 1), above, by noting that "any challenge to the adequacy of AmerGen's acceptance criteria should have been made at the time Citizens filed their initial Petition to Intervene. It cannot be submitted at this late juncture."[58] Thus, the origin, derivation or adequacy of AmerGen's acceptance criteria remained outside the scope of this proceeding.

2.25 On October 20, 2006, Citizens filed a Motion for Leave to File for Reconsideration and Motion for Reconsideration of Order Partially Granting Petition to File a New Contention. They alleged that the Board made clear factual and legal errors in parts of its

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54 *Id.* at 236.

55 *Id.* at 237-255. Challenge 2) was the only portion of Citizens' new contention that the Staff argued was admissible.

56 *Id.*; *see also* Memorandum and Order (Denying AmerGen's Motion for Summary Disposition) at 2 n.4 (June 19, 2007) (unpublished) ("June 19 Order"); LBP-06-07, 63 N.R.C. at 216 n.27 (limiting Citizens' original contention of omission to the sand bed region); LBP-06-16, 63 N.R.C. at 744 (allowing Citizens to file a new contention "raising a specific substantive challenge to AmerGen's new periodic UT program for the sand bed region" and directed that "the substance of [the new contention] must be limited to the sand bed region").

57 LBP-06-22, 64 N.R.C. at 251-53.

58 LBP-06-22, 64 N.R.C. at 240; *see also* June 19 Order at 2 n.4 (confirming the exclusion of the derivation of the acceptance criteria from the admitted contention).

decision on their proposed new contention. Specifically, Citizens averred that the Board erred in rejecting challenges 1) (acceptance criteria), 5) (scope of UT), 6) (quality assurance), and 7) (methods for analyzing UT results) contained in the contention set forth in Citizens' Petition.[59] Citizens did not seek reconsideration of our decision on challenges 3) and 4) discussed in Finding 2.23 above. AmerGen and the Staff opposed Citizens' motion.[60]

2.26 On November 20, 2006, the Board rejected Citizens' Motion for Reconsideration, because it failed to demonstrate any clear and material error in our decision under 10 C.F.R. § 2.323(e).[61]

2.27 On December 20, 2006 Citizens filed another new Motion for Leave to Add Contentions and Motion to Add Contentions. This Motion included two new contentions: the first again alleged potential corrosion in the embedded region of the drywell shell, and the second alleged a failure to address potential corrosion from the drywell shell interior. AmerGen and the Staff opposed Citizens' new contentions, as untimely and lacking in basis, and failing to establish a genuine dispute of material fact.[62]

2.28 On February 6, 2007, Citizens filed yet another Motion for Leave to Add Contention and Motion to Add Contention. This motion challenged the acceptance criteria for drywell shell thicknesses in the sand bed region, arguing that a study by Sandia National Laboratory, released to Citizens on January 15, 2007, showed that the modeling by General

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[59] Motion for Leave to File for Reconsideration and Motion for Reconsideration of Order Partially Granting Petition to File a New Contention at 4-10 (Oct. 20, 2006).

[60] AmerGen's Answer in Opposition to Citizens' October 20, 2006 Motion for Reconsideration (Oct. 30, 2006); NRC Staff Response to Citizens' Motion for Reconsideration (Oct. 31, 2006).

[61] Memorandum and Order (Denying Citizens' Motion for Reconsideration) (Nov. 20, 2006) (unpublished).

[62] AmerGen's Answer to Citizens' Motion for Leave to Add Contentions and Motion to Add Contentions (Jan. 16, 2007); NRC Staff Reply to Citizens' Motion for Leave to Add Contentions and Motion to Add Contentions (Jan. 16, 2007).

Electric, and upon which AmerGen had relied, was based on purportedly deficient assumptions.[63] AmerGen and the Staff opposed the admission of Citizens' new contention.[64]

2.29 On February 9, 2007, the Board denied Citizens' December 20, 2006 Motion for Leave to Add Contentions and Motion to Add Contentions because they were untimely *and* substantively inadmissible under 10 C.F.R. § 2.309.[65]

2.30 On February 26, 2007, the Commission dismissed as moot the pending AmerGen and NRC Staff appeals of the admission of Citizens' now-superseded original contention, because the Board had granted Citizens' petition to file a new contention regarding the drywell shell.[66]

2.31 On March 30, 2007, AmerGen filed a Motion for Summary Disposition on Citizens' Drywell Contention. AmerGen's Motion argued that the hearing record, along with additional sworn affidavits, demonstrated that there was no genuine issue as to any material fact, and that AmerGen was entitled to a decision in its favor as a matter of law. *Id.* at 3. The Staff supported AmerGen's motion,[67] but Citizens opposed it.[68]

2.32 The Staff issued the Final Safety Evaluation Report ("FSER") in April 2007. With respect to drywell shell corrosion, including the sand bed region, the FSER concluded that "the applicant has demonstrated, pursuant to 10 CFR 54.21(c)(1)(iii), that, for the drywell

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[63] Motion for Leave to Add a Contention and Motion to Add a Contention (Feb. 6, 2007).

[64] AmerGen's Answer Opposing Citizens' February 6, 2007 Motion for Leave to Add a Contention and Motion to Add a Contention (Mar. 5, 2007); NRC Staff Answer to Citizens' Motion for Leave to Add a Contention and Motion to Add a Contention (Mar. 5, 2007).

[65] Memorandum and Order (Denying Citizens' Motion for Leave to Add Contentions and Motion to Add Contentions) (Feb. 9, 2007) (unpublished).

[66] CLI-07-08, 65 N.R.C. at 127.

[67] NRC Staff Response to AmerGen's Motion for Summary Disposition (Apr. 26, 2007).

[68] Citizens' Answer Opposing AmerGen's Motion for Summary Disposition (Apr. 26, 2007).

corrosion TLAA [time-limited aging analysis], the effects of aging on the intended function(s) will be adequately managed for the period of extended operation." Staff Exh. 1, at 4-75.

2.33 On April 10, 2007, per 10 C.F.R. § 2.309, the Board denied as incurably late Citizens' February 6, 2007, Motion seeking to add a new contention based on the Sandia National Laboratory study.[69] Although the Sandia study was indeed a new document, the *information* drawn from the report, upon which Citizens' contention was based was not "materially different from that which was previously available."[70]

2.34 On April 17, 2007, following an April 11, 2007 pre-hearing conference call with the parties, the Board issued a Final Scheduling Order. In that Order, the Board established a schedule for completion of mandatory disclosures, answers to AmerGen's Motion for Summary Disposition, the filing of testimony and motions in advance of the evidentiary hearing, and the hearing itself.[71] The Board noted that, during the April 11 conference call, NJDEP had indicated that it did not plan to participate in the hearing as an Interested State, pursuant to 10 C.F.R. § 2.315(c).[72]

2.35 On May 31, 2007, the Board held afternoon and evening sessions in Toms River, New Jersey, to permit members of the public to make limited appearance statements regarding this proceeding. Pursuant to 10 C.F.R. § 2.315(a), none of the statements given at these sessions is evidence in this proceeding.

2.36 On June 1, 2007, the mandatory disclosure process was closed for AmerGen and Citizens. The NRC Staff, however, continued to produce updates to the Hearing File pursuant to

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69 Memorandum and Order (Denying Citizens' Motion for Leave to Add a Contention and Motion to Add a Contention) (Apr. 10, 2007) (unpublished).

70 *Id.* at 6.

71 Memorandum and Order (Prehearing Conference Call Summary, Case Management Directives, and Final Scheduling Order) (Apr. 17, 2007) (unpublished).

72 *Id.* at 3.

10 C.F.R. § 2.1203. Documents exchanged under the mandatory disclosure process are not evidence in this proceeding unless they were admitted as exhibits prior to or at the hearing on September 25 and 26, 2007.

2.37 On June 19, 2007, the Board denied AmerGen's March 30 Motion for Summary Disposition, ruling that "Dr. Hausler's [Citizens' expert witness] version of the facts and his expert opinion derived therefrom demonstrate[d] the existence of genuine issues" of material fact that precluded summary disposition under 10 C.F.R. §§ 1205(c) and 2.710(d)(2).[73] A ruling on the substantive merit of the arguments set forth in AmerGen's Motion for Summary Disposition would have required the Board to "assess the correctness of competing, reasonably supported views embedded in affidavits submitted by the parties' experts."[74]

2.38 In denying summary disposition, the Board also granted in part and denied in part AmerGen's motion to strike portions of Citizens' Answer opposing AmerGen's request for summary disposition; and dismissed as moot AmerGen's motion to strike Citizens response to the NRC Staff's summary disposition answer. Specifically, the Board agreed with AmerGen that Citizens were precluded from raising challenges regarding: (1) the derivation of the acceptance criteria for the drywell shell; (2) the established methods for analyzing UT results; and (3) the scope of the UT monitoring program.[75]

2.39 On June 29, 2007, AmerGen submitted—on behalf of itself, the NRC Staff, and Citizens—a Joint Motion for Clarification on two principal aspects of the Board's June 19 Order. The parties requested clarification of whether, in addition to addressing AmerGen's commitment to conduct UT monitoring in the sand bed region at four-year intervals during the period of

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[73] June 19 Order at 12.

[74] *Id.* at 12 n.13.

[75] *Id.* at 5.

extended operation that would commence in April 2009, Citizens were permitted to address the interval between the 2006 UT monitoring and the next scheduled monitoring in 2008.[76] The parties also disagreed on the interpretation of the language concerning challenges to the analytic methodology in the June 19 Order, and requested clarification.[77]

2.40 In response to the parties' joint motion, the Board issued a Clarifying Memorandum and Order Denying AmerGen's Motion for Summary Disposition.[78] In that Memorandum and Order, the Board stated that Citizens were not permitted to address the interval between the 2006 UT monitoring and the next scheduled monitoring in 2008, because they may not challenge any aspect of AmerGen's UT monitoring program that applies prior to the period of extended operation (*i.e.*, prior to April 2009). Such a challenge is beyond the scope of the proceeding as it constitutes an impermissible attack on the OCNGS CLB contrary to Commission precedent.[79] The Board further stated that Citizens are foreclosed from countering that the methods of calculation or uncertainties contained in AmerGen's statistical analysis are inadequate, or that AmerGen must consider additional uncertainties in performing its analysis.[80] The Board ruled that Citizens may argue that AmerGen has not been consistent in applying its statistical analysis and, accordingly, that AmerGen's asserted corrosion rate is suspect.[81] More specifically, the Board permitted Citizens to seek to demonstrate, for example, that AmerGen has been inconsistent in: (1) its selection of inputs – *i.e.*, actual UT measurements – for deriving the mean thickness and corrosion rate, (2) the manner in which it has applied selected uncertainties

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[76] Joint Motion for Clarification at 2 (June 29, 2007).

[77] *Id.* at 4.

[78] (July 11, 2007) (unpublished) ("July 11 Order").

[79] *E.g.*, *AmerGen Energy Co., LLC* (Oyster Creek Nuclear Generating Station), CLI-06-24, 64 N.R.C. 111, 117-18 (2006).

[80] July 11 Order at 4.

[81] *Id.*

to those measurements, and/or (3) its use of variances in comparison with the acceptance criteria.[82]

2.41 In summary, the Board has ruled that the following issues are outside the scope of this proceeding:

- Any challenge to the adequacy of AmerGen's moisture monitoring program.[83] This includes AmerGen's Protective Coating Monitoring and Maintenance Program ("PCMMP"), AmerGen's plans for periodic visual inspections of the multi-layer epoxy coating system on the exterior of the sand bed region of the drywell and any challenges to the adequacy of AmerGen's commitments to identify water leakage and initiate corrective actions to address any leakage that might be discovered.[84]

- Any challenge to AmerGen's response to wet conditions and coating failure.[85]

- Any challenge to the spatial scope of AmerGen's UT monitoring regime.[86]

- Any challenge to the adequacy of AmerGen's quality assurance program for UT measurements.[87]

- Any challenge to AmerGen's "statistical techniques" and methodology for determining a corrosion rate.[88] This includes uncertainties associated with performing the statistical analysis and margin calculation.[89]

- The potential existence of continuing corrosion in the upper region of the drywell liner.[90]

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[82] *Id.*

[83] LBP-06-22, 64 N.R.C. at 247.

[84] *Id.* at 246.

[85] *Id.* at 245, 247; *see also* June 19 Order at 2 n.4.

[86] LBP-06-22, 64 N.R.C. at 249-51; *see also* June 19 Order at 2 n.4.

[87] LBP-06-22, 64 N.R.C. at 253; *see also* June 19 Order at 2 n.4.

[88] LBP-06-22, 64 NRC at 254-55; *see also* June 19 Order at 2 n.4. More specifically, Citizens are "foreclosed" from arguing "that the methods of calculation or uncertainties contained in AmerGen's Statistical Analysis are inadequate, or that AmerGen must consider additional uncertainties in performing its analysis." July 11 Order at 4.

[89] July 11 Order at 4.

[90] Memorandum and Order (Denying NIRS's Motion for Reconsideration) at 7-8 (Apr. 27, 2006); *see also* LBP-06-07, 63 N.R.C. at 216 n.27.

- The adequacy and derivation of AmerGen's acceptance criteria.[91]

- AmerGen's UT monitoring program for the embedded region of the drywell shell.[92]

- Any aspect of AmerGen's UT monitoring program that applies prior to the period of extended operation (*i.e.*, prior to April 2009).[93]

2.42 Thus, after numerous motions and requests for various issues to be litigated in this proceeding, the sole remaining contention that is the subject of this Initial Decision, is as follows:

> AmerGen's scheduled UT monitoring frequency in the sand bed region [during the period of extended operation] is insufficient to maintain an adequate safety margin. More precisely, ... that the issue presented is whether, in light of the uncertainty regarding the existence vel non of a corrosive environment in the sand bed region . . . AmerGen's UT monitoring plan is sufficient to ensure adequate margins.[94]

2.43 In accordance with our April 17 Order, the parties submitted pre-filed direct testimony, briefs and exhibits on July 20, 2007. The parties submitted their rebuttal and surrebuttal filings on August 17, and September 14, respectively.

2.44 The parties also submitted motions in limine regarding the pre-filed testimony and briefs. The Board granted, in part, AmerGen and the Staff Motions in Limine following direct testimony, and denied all other such motions.[95] Specifically, the Board excluded certain arguments made by Citizens regarding: the spatial scope of UT measurements; alleged inaccuracies in those measurements; the derivation of the acceptance criteria; the application of

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91 LBP-06-22, 64 N.R.C. at 240; June 19 Order at 2 n.4.

92 *See* Memorandum and Order (Denying Citizens' Motion for Leave to Add Contentions and Motion to Add Contention) at 7-15 (Feb. 9, 2007) (unpublished).

93 *See* July 11 Order at 2.

94 June 19 Order at 2 (citations and internal quotations omitted).

95 Memorandum and Order (Ruling on Motions in Limine and Motion for Clarification) (Aug. 9, 2007) (unpublished) ("August 9 Order"); Memorandum and Order (Ruling on Motion to Conduct Cross-Examination and Motions In Limine) (Sept. 12, 2007) (unpublished) ("September 12 Order"), and Memorandum and Order (Ruling on Motions In Limine) (Sept. 21, 2007) (unpublished).

the acceptance criteria in the current license term; and real-time corrosion-monitoring.[96] In an August 9 Order, the Board refrained from "actually expunging" excluded material, but stated that it would instead "accord it no weight."[97]

2.45 The August 9 Order also requested that the parties provide answers to twelve specific questions in their rebuttal testimony. Those questions addressed a variety of topics, including the statistical analysis of UT data, potential systematic errors in UT measurements, the definition of "reasonable assurance" as applied in this proceeding, and background information to aid the Board's understanding of the GE analyses used to develop the acceptance criteria. Each party submitted answers to these questions as directed.

2.46 On August 24, Citizens submitted a motion to cross-examine Mr. Peter Tamburro, a witness for AmerGen, pursuant to 10 C.F.R. § 2.1204(b)(3). Citizens' motion argued that cross examination was necessary to resolve alleged inconsistencies between Mr. Tamburro's testimony and other technical documents he authored.[98] AmerGen and the NRC Staff opposed the motion.[99]

2.47 On September 12, the Board issued a Memorandum and Order denying all motions in limine regarding rebuttal testimony and denying Citizens' motion to cross-examine Mr. Tamburro.[100] On the same day, it issued another Memorandum and Order setting forth hearing directives including the following five additional topics to be discussed in greater depth at the evidentiary hearing: (1) the definition of "reasonable assurance" in license renewal proceedings; (2) uncertainty in UT measurements; (3) the likely site(s) of future corrosion in the

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96 August 9 Order.

97 *Id.* at 2.

98 September 12 Order

99 *Id.* at 1 n.2.

100 *Id.*

sand bed region; (4) the acceptance criteria for thickness measurements, with the understanding that such "inquiries should not be construed as questioning the validity" of the criteria; and (5) AmerGen's commitment to use strippable coating to control reactor cavity leakage during "forced" outages when the reactor cavity was filled with water.[101] The latter Order also required Citizens to redact from their direct testimony certain material previously ruled to be inadmissible, altering our stance that such testimony would simply be accorded no weight.[102]

2.48 On September 20, the Board held an administrative hearing at the NRC Headquarters in Rockville, Maryland, for the purpose of admitting the parties' pre-filed testimony and exhibits into evidence.

2.49 On September 24 and 25, 2007, the Board held an evidentiary hearing on the admitted contention in Toms River, New Jersey. The testimony at the hearing was presented in six panels: (1) drywell physical structure, history, and commitments; (2) acceptance criteria; (3) available margin; (4) sources of water; (5) the epoxy coating system; and (6) future corrosion. The purpose of the evidentiary hearing was not for the parties to reargue positions filed with the Board in pre-filed testimony, but rather for Board members to ask questions of the parties in areas where we required further clarification. Accordingly, the intensity of the Board's questioning varied greatly from panel to panel. In response to questions, the parties' witnesses presented live testimony and submitted exhibits. We considered all of this testimony and these exhibits in reaching our decision today.

2.50 On October 10, 2007, the parties submitted their proposed findings of fact and conclusions of law in the form of a proposed Initial Decision by the Board.

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[101] Memorandum and Order (Hearing Directives) at 4-5 (Sept. 12, 2007) (unpublished).

[102] *Id.* at 2, Attach. A.

III. LEGAL STANDARDS

3.1 The standards governing the issuance of renewed licenses for operating commercial nuclear power plants are set forth in 10 C.F.R. §§ 54.21 and 54.29. 10 C.F.R. § 54.21(a)(3) requires the applicant to "demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB for the period of extended operation." Under 10 C.F.R. § 54.29(a), the applicant must identify and take (or plan to take) actions to manage the effects of aging on the functionality of the sand bed region of the drywell "such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB . . . ."

3.2 Taken together, these regulations require AmerGen to establish an AMP that is adequate to provide reasonable assurance that the drywell will be maintained and continue to perform its intended functions consistent with the CLB for an additional twenty years.

3.3 As the Commission has reaffirmed in the course of this proceeding, issues related to the OCNGS CLB are outside the scope of the license renewal process. "[R]eview of a license renewal application does not reopen issues relating to a plant's current licensing basis, or any other issues that are subject to routine and ongoing regulatory oversight and enforcement."[103]

3.4 Reasonable assurance under 10 C.F.R. § 54.29 does not require absolute certainty, but only a demonstration that the applicant's AMP is reasonable in light of the relevant circumstances. For example, in *North Anna Envtl. Coalition v. NRC*, an intervenor argued that "reasonable assurance of safety" required proof beyond a reasonable doubt.[104] The U.S. Court of Appeals for the District of Columbia Circuit rejected this view: "[h]ad the regulations been

[103] CLI-06-24, 64 N.R.C. at 117-18; *see also* July 11 Order at 2 ("an attack on AmerGen's current licensing basis . . . is beyond the scope of this proceeding.").

[104] 533 F.2d 655, 658 (D.C. Cir. 1976).

intended to require proof beyond a reasonable doubt we believe it would have been clearly so stated."[105] Similarly, the Commission has ruled that "'reasonable assurance' does not mean a demonstration of near certainty...."[106] In the context of this proceeding, AmerGen is not required to demonstrate that additional corrosion of the drywell is impossible.[107] Instead, AmerGen must demonstrate that its AMP, in light of the known or likely circumstances, provides reasonable assurance that it will maintain the drywell and ensure performance of its intended function in accordance with the CLB throughout the period of extended operation.

3.5 The Board has assessed Citizens' challenge to the frequency of AmerGen's planned UT of the sand bed region with the understanding that the UT inspection program frequency is only one *part* of AmerGen's overall AMP for the drywell shell. If AmerGen's AMP for managing corrosion in the sand bed region, taken as a whole, provides the requisite reasonable assurance, then AmerGen satisfies the applicable requirements of 10 C.F.R. Part 54.

3.6 The subject of "reasonable assurance" became a particular issue in the hearing in the context of Citizens' arguments that AmerGen must establish the available "margin" between the applicable acceptance criteria and the current actual thickness of the drywell shell in the sand bed region with a statistically-calculated 95% confidence level. We disagree. A 95% confidence level is necessary neither for reasonable assurance nor for compliance with 10 C.F.R. § 50.55a in this proceeding. ASME Code, Section XI, Subsection IWE, provides criteria for inspection and

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105 *Id.* at 667.

106 *Public Service Co. of New Hampshire* (Seabrook Station, Units 1 & 2), CLI-78-1, 7 N.R.C. 1, 18 (1978); *see also* Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV, 66 Fed. Reg. 55,732, 55,739-40 (Nov. 2, 2001) (rejecting the view that use of "reasonable assurance" as a basis for judging compliance compels a focus on extreme values).

107 *See Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), CLI-01-17, 54 N.R.C. 3, 4 (2001) ("Adverse aging effects generally are gradual and thus can be detected by programs that ensure *sufficient* inspections and testing.") (emphasis added); *cf. Yankee Atomic Electric Co.* (Yankee Nuclear Power Station), CLI-96-7, 43 N.R.C. 235, 261-62 (1996) (rejecting intervenors' claim that owners' ability to pay decommissioning costs was "not ironclad").

evaluation of the drywell shell. There is no requirement that the data be evaluated using 95% confidence. AmerGen's approach of using the average thickness values to establish the available margin (a topic that will be discussed in more depth later) was reviewed by the NRC Staff. The methodology is appropriate for UT data evaluation and is part of the CLB, as explained in Section V, below.

3.7 Further, there is no legal or regulatory requirement that mandates analyzing this single aspect of the AMP (*i.e.*, the available margin to the acceptance criteria) using a 95% confidence level. The Board so rules for three independent reasons. First, the ASME Code criteria used by AmerGen and the Staff are part of the OCNGS CLB. As explained above, a challenge to the CLB is outside the scope of this proceeding. Second, as noted in Finding 3.5, above, reasonable assurance is determined by an assessment of the whole AMP, not by an assessment of a single particular aspect of the program. Third, judicial precedent interpreting the Atomic Energy Act in no way mandates that reasonable assurance must be demonstrated by the use of a 95% statistical confidence level. This is the case with respect to the adequacy of the *overall* AMP for the drywell shell, and is certainly the case as applied to individual issues such as the current "margin" from the applicable acceptance criteria. Under these circumstances, the Board will defer to the NRC Staff's reasonable technical judgment on this point. As the court recognized in *Siegel v. Atomic Energy Comm'n*, "Congress . . . enact[ed] a regulatory scheme which is virtually unique in the degree to which broad responsibility is reposed in the administering agency, free of close prescription in its charter as to how it shall proceed in achieving the statutory objectives."[108] Thus, in this case, there is a reasonable technical basis for

[108] 400 F.2d 778, 783 (D.C. Cir. 1968), cert. denied, 439 U.S. 1046 (1978); *see also Massachusetts v. NRC*, 878 F.2d 1516, 1523 (1st Cir. 1989).

the Staff's determination, that, "a pure statistical analysis is not a prerequisite for review and acceptance." Staff Rebuttal Testimony, A.11.

IV. BACKGROUND ON THE DRYWELL SHELL SAND BED REGION AND THE HISTORICAL CORROSION ISSUE

4.1 The following section provides background on the drywell shell sand bed region and the historical corrosion that occurred in that region.

A. Witness Backgrounds

4.2 The background on the drywell shell sand bed region and the historical corrosion issue presented below is based primarily on the direct testimony of three witnesses for AmerGen.[109] *See* AmerGen's Pre-filed Direct Testimony Part 1: Introduction, Drywell Physical Structure, History, and Commitments ("AmerGen Dir. Part 1").

4.3 AmerGen's witnesses on this topic included Mr. Michael P. Gallagher, Mr. Frederick W. Polaski, and Mr. John F. O'Rourke. Mr. Gallagher is Vice President for License Renewal for Exelon, and has 26 years of experience in the nuclear industry. AmerGen Dir., Part 1, A.1. Mr. Polaski is the Manager of License Renewal for Exelon, and has 36 years of experience in the nuclear industry. *Id.* Mr. O'Rourke is the Senior Project Manager, License Renewal, for Exelon, has 34 years of experience in the nuclear industry, and from 2003 to 2006 was the Assistant Site Engineering Director at OCNGS. *Id.*

B. Function and Physical Characteristics of the Drywell

4.4 The relevant intended functions of the drywell shell, as part of the OCNGS primary containment, are to accommodate the pressures and temperatures resulting from the break of any enclosed process pipe, and to provide structural support to the reactor pressure

[109] The Board relies on AmerGen's testimony in this section because only AmerGen provided thorough testimony on this topic, and because neither Citizens nor the Staff contradicts AmerGen's testimony on the physical description of the plant and the history of the corrosion issue as presented here.

vessel, the reactor coolant systems, and other systems, structures, and components housed within. AmerGen Dir., Part 1, A.8.

4.5 The drywell shell is made of carbon steel plates that are welded together in the shape of an inverted light bulb. It is surrounded by a concrete shield wall. AmerGen Dir., Part 1 A.7. The drywell shell is approximately 70 ft. in diameter in its spherical section and 33 ft. in diameter in its cylindrical section. *Id.* At the time of construction, the drywell shell was coated on the inside surface with inorganic zinc (Carboline carbozinc 11) and on the outside surface with "Red Lead" primer (TT-P-86C Type I). *Id.* The shell is connected to the torus[110] through ten cylindrical vent headers. *Id.* Applicant's Exhibits 4 and 5 show the general containment structure design.

4.6 The drywell shell is embedded in a concrete pedestal atop the Reactor Building concrete foundation, as shown in Applicant's Exhibit 4. The bottom of the drywell shell sits at approximately elevation 2'3" (as shown in Applicant's Exhibit 5) and the top is at an elevation of approximately 100', relative to mean sea level. AmerGen Dir., Part 1, A.7.

4.7 The drywell shell was designed with a "sand bed" on its exterior between, approximately, elevations 8'11" and 12'3" to structurally support the shell as it transitions from being embedded in concrete on both sides below elevation 8'11", to being embedded only on the interior. AmerGen Dir., Part 1, A.9. The drywell shell is embedded in concrete on both sides from its bottom until approximately elevation 8'11", where the exterior drywell shell concrete floor is located. *Id.* From elevation 8'11" upwards to approximately elevation 11'0" (beneath the torus vent headers) and elevation 12'3" (areas between the torus vent headers), the shell is embedded in concrete only on the interior, except at the location of two trenches excavated in the

[110] The torus is a torroidal-shaped steel pressure vessel encircling the base of the drywell. AmerGen Dir. Part 1 at A.11. It is partially filled with demineralized water. *Id.* One of the functions of the torus is to provide pressure suppression in the event of a loss-of-coolant accident. *Id.*

concrete floor in the 1980s for UT measurements. *Id.* The sand was removed in the early 1990s, after which the exterior surface of the drywell shell in the sand bed region was cleaned and coated with a multi-layer epoxy coating system. *Id.* Applicant's Exhibits 4 and 7 show the location of the "sand bed region."

4.8 The sand bed region of the shell is spherical and is divided into ten "bays," each of which has an associated torus vent header. AmerGen Dir., Part 1, A.10. The ten bays are designated with the odd numbers one through nineteen. *Id.* This is shown in Applicant's Exhibits 5, 6, and 7. Five drains, equally spaced throughout the bays and located within the concrete floor of the external sand bed region ("sand bed drains"), are designed to drain water that might reach the sand bed floor into the torus room below. *Id.* Water from these drains is diverted through plastic tubing where it can be collected in five-gallon plastic bottles. *Id.*

4.9 There are two trenches that were excavated in 1986 from the interior concrete floor in Bays 5 and 17. AmerGen Dir., Part 3, A.12; Tr. at 68 (Gallagher). Bay 5 was selected in 1986 because it was believed to have little external corrosion. Tr. at 406 (Polaski). Conversely, Bay 17 was selected because it was believed to have severe external corrosion. *Id.* The Bay 17 trench has its base at approximately elevation 9'3". Applicant's Ex. 28 and Tr. at 92 (Gallagher) (vertically to scale); Tr. at 407 (Polaski). The bottom of that trench is the lowest elevation from which AmerGen has UT grid data on severely corroded surfaces. Tr. at 406 (Polaski). The trench in Bay 5 is deeper than Bay 17, but Bay 5 has little corrosion and Bay 17 has severe corrosion on the exterior. Data in trenches 5 and 17 show significant differences in thickness.

4.10 Above the sand bed region, the drywell shell is within a few inches of the concrete shield wall, as can be seen in Applicant's Exhibits 4 and 7. The small gap between the shell and the shield wall was filled during construction with a compressible, inelastic, asbestos fiber-magnesite cement product known as "Firebar-D." After construction completion, this material was compressed by heating and pressurizing the drywell to compress the filler material and subsequently provide an air gap to allow free expansion of the drywell under design basis loads and postulated events ("expansion gap"). AmerGen Dir., Part 1, A.12. Above approximately 71'6", the upper drywell shell transitions from a spherical to a cylindrical shape. The reactor cavity is located above the upper drywell. AmerGen Dir., Part 1, A.12.

4.11 The reactor cavity (or "refueling cavity") is located at the top of the Reactor Building concrete shield wall, as shown in Applicant's Exhibit 4. This cavity is only filled with water during refueling outages, or potentially in the rare event of a non-refueling outage when the reactor vessel must be opened. AmerGen Dir., Part 1, A. 13; AmerGen Surr., Part 1, A.4; Tr. at 57-58 (Gallagher); Tr. at 414-416 (O'Rourke).

4.12 The reactor cavity drainage system is designed with a concrete trough that is located below the reactor cavity bellows seal to collect water that might leak while the reactor cavity is filled with water. AmerGen Dir., Part 1, A.14. The location of the concrete trough is identified in Applicant's Exhibit 4, and the trough detail appears as Applicant's Exhibit 8. This trough is equipped with a 2" drain line designed to direct leakage to the Reactor Building equipment drain tank and prevent its entering the gap between the drywell shell and the concrete shield wall. *Id.* During those outages in which the reactor cavity is filled with water, leakage is minimized through the application of stainless steel tape and strippable coating to the reactor cavity liner. *Id.*

4.13 OCNGS operates on a two-year refueling cycle. Thus, under normal circumstances, the reactor cavity is only filled with water for less than 26 days once every two years. Tr. at 414 (O'Rourke). During the last refueling outage in 2006, the reactor cavity was only filled with water for about 17 days. Tr. at 417 (Ray).

4.14 The average normal operating temperature inside the drywell is 139° F. AmerGen, Dir. Part 1, A.18. During operations, maximum expected temperature at the exterior sand bed region is approximately 109.5° F. Tr. at 519 (Hosterman). During outages, expected sand bed region temperatures range up to about 90° F. *Id.* at 515 (Hosterman).

4.15 Measured radiation levels inside the drywell at the sand bed elevation are in the range of 4.7 to 5.6 rads per hour, of primarily gamma radiation. While the expected radiation levels at the drywell exterior in the sand bed region would be slightly lower, these values can be used as conservative estimates of exterior sand bed region radiation levels. AmerGen Dir. Part 1, A.19.

C. Historical Discovery of Corrosion and Its Causes

4.16 OCNGS began operation in 1969. AmerGen Dir., Part 1, A.20. In the 1980s, the previous owner discovered water coming from some of the sand bed drains. *Id.* Extensive investigations were performed to identify the source of water and the leakage path. *Id.* The source of the water was subsequently determined to be leakage through small cracks in the reactor cavity liner. *Id.* This leakage occurred when the reactor cavity was filled with water, and should have been collected by the concrete trough located beneath the reactor cavity bellows. *Id.* The amount of water, however, was greater than the capacity of the trough and drain pipe. *Id.* Furthermore, the curb of the trough did not contain the water because of defects in the trough lip and a blocked drain, so the water instead overflowed into the expansion gap and down to the sand bed region. *Id.* The trough lip defects and leakage path are shown in Applicant's Exhibits 7, 8 and 9. *Id.* Later, prior to a completion of historical corrective actions, the sand bed drains were discovered to be clogged, preventing proper drainage of water once it reached the sand bed region. *Id.* Finally, portions of the sand bed floor were not properly finished to allow drainage towards the sand bed drains. *Id.*

4.17 The presence of water from the reactor cavity, sand (acting to keep the water in direct contact with an uncoated drywell shell), along with improper sand bed drainage caused corrosion of the exterior of the drywell shell prior to the implementation of corrective actions. AmerGen Dir., Part 1, A.21. The corrosion was not evenly distributed either among or within the ten bays. *Id.* at A.22. In general, corrosion was greatest in the vicinity of the torus vent headers and not between these headers. *Id.* In addition, there was an air-water interface located near the top of the sand, between approximately elevations 11' and 12' in most bays, above which there was virtually no corrosion. *Id.* For reference, the as-designed thickness of the drywell shell in the sand bed region is 1.154". *Id.* The uneven distribution of corrosion resulted in a maximum general average metal loss of about 0.35" in part of Bay 19. *Id.* Some bays exhibited almost no observable corrosion. *Id.*

D. Corrective Actions to Arrest Corrosion

4.18 OCNGS took multiple mitigating actions in the 1980s and early 1990s to address the corrosion problem, including:

- clearing of the sand bed drains;
- boring ten access holes through the concrete shield wall to access the ten bays to completely remove the sand;
- manual cleaning of the exterior shell;
- application of a multi-layer epoxy coating system on the drywell shell exterior in the sand bed region;
- repair of the concrete floor located between the exterior surface of the drywell shell and the concrete shield wall in those bays that required repair;
- application of epoxy caulk at the drywell shell/concrete floor junction in the former sand bed region;

- repair of the leakage collection trough and clearing of the trough drain; and
- application of stainless steel tape and a strippable coating to the reactor cavity during refueling outages to seal cracks in the reactor cavity liner and reduce leakage. Tape and strippable coating were not applied, however, during the refueling outages in 1994 and 1996.

AmerGen Dir., Part 1, A.23.

4.19 AmerGen's regulatory commitments relating to aging management of the drywell are part of its ASME Section XI, Subsection IWE Primary Containment Inspection Program contained in Appendix A of the OCNGS LRA. AmerGen Dir., Part 1, A.25. This aging management program is intended to provide reasonable assurance that the effects of aging will be adequately managed, so that the intended functions of the drywell will be maintained consistent with the CLB for the period of extended operation. *Id.* The regulatory commitments under this program are contained in a letter from Michael P. Gallagher, Vice President for License Renewal for Exelon, to the NRC, dated February 15, 2007, titled "Additional Commitments Related to the Aging Management Program for the Oyster Creek Drywell Shell, Associated with AmerGen's License Renewal Application." *Id.* at A.26.. A copy of the letter is provided in Applicant's Exhibit 10.

4.20 During the 2006 refueling outage, debris was found in two of the five sand bed drains. Tr. at 517 (Tamburro). AmerGen's internal procedures include periodic inspections of the sand bed drains to verify they are clear of blockage. Tr. at 518 (Tamburro). AmerGen has made no formal regulatory commitment to perform these inspections (Tr. at 518 (Gallagher)), but at the hearing, Mr. Gallagher expressed AmerGen's willingness to make such a commitment. Tr. at 569 (Gallagher). Thus, as a condition of the renewed license, AmerGen will be required to commit to periodically inspect the sand bed drains for blockage, consistent with its existing internal procedures.

V. ACCEPTANCE CRITERIA

5.1 The following section addresses the applicable acceptance criteria governing the thickness of the drywell shell in the sand bed region. These criteria are part of the OCNGS CLB as explained below. While the derivation or adequacy of the acceptance criteria are not within the scope of the admitted contention, it was necessary to develop an understanding of what those criteria are in order to establish the current available margin. What follows is an introductory section identifying the witnesses who provided the testimony on this issue, as well as a summary of their backgrounds and qualifications. Next, is a summary of the testimony regarding the acceptance criteria, followed by the Board's conclusions. These criteria are then compared with the actual measured thickness of the drywell shell to identify the available margin in Section VI, below.

A. Witness Backgrounds

5.2 The information presented below regarding the drywell shell sand bed region thickness acceptance criteria is based on the testimony of four witnesses for AmerGen, four witnesses for the NRC Staff, and one witness for Citizens.

5.3 AmerGen's witnesses on this topic included Mr. Michael P. Gallagher, Mr. Peter Tamburro, Mr. Ahmed Ouaou, and Dr. Hardayal S. Mehta. Mr. Gallagher's qualifications were previously discussed. Mr. Tamburro is a Senior Mechanical Engineer in the Engineering Department at OCNGS, where he has been involved in the drywell shell corrosion issue since 1988. AmerGen Dir., Part 2, A.4. Mr. Ouaou is a registered professional engineer and independent contractor working at Exelon's Kennett Square, Pennsylvania offices, and has over thirty years of civil/structural engineering experience, mostly in the nuclear industry. AmerGen Dir., Part 4, A.1. Dr. Mehta is a Chief Consulting Engineer-Mechanics with GE-Hitachi Nuclear

Energy Co., has over 30 years of experience in the areas of stress analysis, linear-elastic and elastic-plastic fracture mechanics, residual stress evaluation, and ASME Code related analyses pertaining to boiling water reactor components, and was involved in the preparation of "GE Letter Report, "Sandbed Local Thinning and Raising the Fixity Height Analyses (line Items 1 and 2 in Contract # PC-0391407)," dated December 11, 1992." This document is Applicant's Exhibit 39, and provides GE's analysis of what later became the "local buckling criterion." *See* Applicant's Exh. 36.

5.4 The NRC Staff witnesses on this topic included Dr. Mark Hartzman, Mr. Hansraj G. Ashar, Dr. James Davis, Mr. Timothy L. O'Hara and Mr. Arthur D. Salomon. Tr. at 115 (Baty). Dr. Hartzman is employed by the NRC as a Senior Mechanical Engineer in the Division of Engineering, Office of Nuclear Reactor Regulation ("NRR"), and has over 48 years of experience in engineering mechanics and structural analysis, including over 32 years of experience in nuclear regulatory review and evaluation. Staff Exh. D at 11. Mr. Ashar is employed by the NRC as a Senior Structural Engineer in the Division of Engineering, NRR, and has 44 years of engineering experience, including 33 years as a Structural Engineer and Senior Structural Engineer with the NRC. Staff Exh. D at 2. Dr. Davis is employed by the NRC as a Senior Materials Engineer in the Division of License Renewal, NRR, and has over 39 years of material engineering experience, including over 20 years in the nuclear power industry. Staff Exh. D at 7. Mr. O'Hara is employed by the NRC as a Reactor Inspector in the Region 1 Office, has over 35 years of engineering management experience, primarily in the nuclear field, and has been a Reactor Inspector for the NRC since 2002. *See* Staff Exh. D at 14-17. Mr. Salomon is employed by the NRC as a Research (Mathematical) Statistician in the Probabilistic Risk

Analysis Branch in the Office of Nuclear Regulatory Research, and has nearly 30 years of experience in the fields of statistics and systems engineering. Staff Exh. D at 19-22.

5.5 Citizens' witness on the topic of acceptance criteria was Dr. Rudolf Hausler. Dr. Hausler is the President of Corro-Consulta, a private consulting company in Dallas and Kaufman, Texas. Citizens' Exh. D at 1. He holds a Ph.D in chemical engineering from the Swiss Federal Institute of Technology in Zurich, Switzerland, and has over 30 years of experience in planning, conducting, and directing advanced chemical research focused on oil production and processing additives, including expertise in corrosion prevention, chemical inhibition, materials selection, failure analysis, troubleshooting and economic analysis. *Id.*

5.6 Due to his acknowledged lack of structural engineering experience, (Tr. at 171 (Hausler)), when Dr. Hausler's testimony on the acceptance criteria conflicts with that of the witnesses for AmerGen and the Staff, Dr. Hausler's testimony will be given less weight than that of other witnesses.

B. Background and Testimony on the Acceptance Criteria

5.7 AmerGen's direct testimony, provided by Mr. Tamburro and Mr. Gallagher, addressed the relevant background information on the development of the acceptance criteria for drywell shell thickness in the sand bed region at OCNGS. The drywell shell was designed with a sand bed on the exterior of the drywell shell between approximately elevations 8'11" and 12'3" to structurally support the shell as it transitions from being embedded in concrete on both sides below elevation 8'11." AmerGen Dir., Part 2, A.8. In the 1980s, OCNGS identified the presence of water from the reactor cavity, sand (acting to keep the water in direct contact with an uncoated drywell shell), along with improper sand bed drainage as a cause of corrosion of the exterior of the drywell shell. *Id.* General Electric ("GE") was retained to analyze the structural integrity of the drywell shell in this region if the sand were removed. *Id.*

5.8 The drywell shell in the sand bed region has two modes of potential failure, which are referred to as "buckling," caused by physical loads and stresses, and "pressure," caused by internal pressure. AmerGen Dir., Part 2, A.9. These two modes occur under different postulated accidents. *Id.* The limiting buckling scenario occurs during a postulated accident when the reactor is shutdown, the reactor cavity is filled with water, an earthquake occurs, and the drywell is under a negative pressure of 2 psi. *Id.* Under these postulated loading conditions, the various loads apply extreme compressive stresses on the drywell shell. *Id.* The limiting pressure scenario occurs during a postulated loss-of-coolant accident ("LOCA") while the reactor is at full power, resulting in tensile stresses on the drywell shell. *Id.*

5.9 There are three acceptance criteria that are part of the CLB for the drywell shell in the sand bed region and that are derived from the analyses performed by GE in the early 1990s: two criteria for buckling and one for pressure. AmerGen Dir., Part 2, A.14; Applicants' Exhibit 27 at 17-18.

5.10 The first buckling criterion, the "*general buckling criterion*" is a general average thickness of 0.736." AmerGen Dir., Part 2, A.14. An area of average thickness less than 0.736" remains adequate if it meets the second buckling criterion called the "*local buckling criterion.*" *Id.* The local buckling criterion looks like a "tray" as shown in Applicants' Exhibit 11. *Id.* The center of the tray is 0.536" covering a 12" by 12" area, with a one-foot transition to the surrounding shell to a uniform thickness of 0.736." *Id.* The transition area translates into a total contiguous area with thickness below 0.736" of nine square feet with a volume of 124.8 cubic inches. *Id.* This criterion takes into account factors such as the location of the tray within the bay and configuration. *Id.*

5.11 The two buckling criteria are volumetric criteria. AmerGen Dir., Part 2, A.15. This is best explained by using the local buckling criterion. The total volume of this tray that is missing, with respect to a plate with a uniform thickness of 0.736", is 124.8 cubic inches. *Id.* Therefore, this criterion is not exceeded when localized corrosion removes a couple or even tens of cubic inches from the tray. *Id.* The entire tray, on average, needs to corrode away for that loss of metal to be significant from a buckling perspective and to exceed the local buckling criterion. *Id.*

5.12 The third acceptance criterion, the "*pressure criterion*" is a local area average criterion with a thickness of 0.490" that is no more than 2.5" in diameter. AmerGen Dir., Part 2, A.14. Therefore, only a small area of metal needs to be removed from a localized area of the shell to exceed its ability to retain internal pressures. *Id.* at A.12. For example, a very small hole in the shell would exceed the applicable ASME Code criteria for pressure, because any hole in the shell will allow internal pressure to escape. *Id.* That same small hole, however, would have no effect on buckling. *Id.*

5.13 The Staff's direct testimony is consistent with AmerGen's direct testimony on acceptance criteria. *See* Staff Dir., A.7-A.9. The Staff concurs that the three acceptance criteria identified by AmerGen are part of the CLB. *Id.* at A.7.

5.14 In Dr. Hausler's direct testimony for Citizens, he identified alleged inconsistencies in the application of the local 0.536" buckling criterion. Specifically, he stated that, in OCNGS documents, the "acceptance criterion applied to such [locally-thinned] areas has varied from requiring them to be smaller than one square foot to allowing them to be as large as nine square feet." Citizens' Dir., A.13. Dr. Hausler also identified alleged inconsistencies in the minimum thickness value used for locally-thinned areas. Instead of 0.536", Dr. Hausler discussed instances where a 0.636" minimum thickness value was used (Citizens' Dir., A.13), where a value of 0.536" was used over a one square foot area (Citizens' Dir., Att. 5, at 2), and where a value of 0.693" was used over a 6" by 6" area (Citizens' Dir., Att. 5, at 3-4).

5.15 AmerGen's witnesses addressed Citizens' argument that the acceptance criteria have been applied inconsistently over time. *See* AmerGen Dir. Part 2, A.17-A.20. OCNGS has, at times, used different calculation-specific values in UT thickness evaluations. In each case, the calculation specific value was more conservative than the CLB acceptance criteria. *Id.* at A.18. This is a reasonable method because evaluation against a more conservative value demonstrates compliance with the actual acceptance criteria. *Id.* at A.20. At the hearing, Mr. Tamburro responded directly to Dr. Hausler on this point, explaining that the more conservative values used in specific calculations did not alter the CLB acceptance criteria. Tr. at 149-50 (Tamburro).

5.16 In our August 9, 2007 Order, and again in our September 12 Order (Hearing Directives), the Board raised a number of questions regarding the GE analysis used as the basis for determining the acceptance criteria, and the assumptions underlying the analysis. The Board did so to obtain essential background information to help us understand what the CLB is. As pointed out in the September 12 Order (Hearing Directives),[111] and as reiterated at the hearing, the Board recognizes that the origin, derivation, and adequacy of the acceptance criteria that are part of the OCNGS CLB are outside the scope of this proceeding. Tr. at 151 (Judge Abramson).

[111] "[A]lthough we may ask questions about the derivation of the acceptance criteria . . . our inquiries should *not* be construed as questioning the validity of the acceptance criteria. Nor should our inquiries about non-litigable topics be construed as rendering those topics litigable. Rather, the purpose of such questions is to acquire an understanding of the subject matter sufficient to enable us to accompany our decision with a fully explicated rationale." September 12 Order (Hearing Directives) at 4-5 n.4 (emphasis in original).

5.17 In response to additional questions from the Board at the September 5, 2007 pre-hearing conference and Question 4 in our September 12 Order (Hearing Directives), AmerGen and the Staff provided the following information regarding the documentation of the acceptance criteria as part of the CLB.

- The 0.736" general buckling criterion is part of the CLB through the NRC's approval of this criterion in an April 1992 NRC Safety Evaluation (Applicant's Exhibit 37). AmerGen Surr., Part 2, A.3.

- The local buckling criterion (0.536" in the tray configuration described above and as shown in Applicant's Exhibit 11) and the pressure criterion (0.490" over circular areas of diameters up to 2.5") are part of the CLB as documented in the design basis information contained in the OCNGS UFSAR. Relevant pages of the UFSAR were included in Applicant's Exhibit 38. AmerGen Surr., Part 2, A.3; *see also* Staff Surr., A.42.

- UFSAR Section 3.8.2.5, entitled "Structural Acceptance Criteria" states: "The Basic Design phase of the Containment System is given in Subsection 3.8.2.4 and the references listed in Subsection 3.8.6. These reference documents must be addressed to obtain complete information." AmerGen Surr., Part 2, A.3; *see also* Staff Surr., A.42.

- UFSAR Section 3.8.2.8, entitled "Drywell Corrosion" states: "The results of the [1992 refueling outage] inspection and the structural evaluation of the "as found" condition of the vessel is [*sic*] contained in Reference 44 [TDR-1108]." AmerGen Surr., Part 2, A.3; *see also* Staff Surr., A42.

- Reference 44 is listed in UFSAR Section 3.8.6 as the "GPUN Technical Data Report TDR-1108, 'Summary Report of Corrective Action Taken from Operating Cycle 12 through 14R', April 28, 1993," which is Applicant's Exh. 27.

- Page 17 of TDR-1108 identifies the local buckling criterion as a shell of uniform thickness of 0.736" with a local area with reduced thickness of 0.200" (*i.e.*, 0.536") in an area 12" x 12" in the sand bed region, tapering to original thickness over an additional 12", located midpoint between the torus vent penetrations. This is correctly depicted in Applicant's Exhibit 11. AmerGen Surr. Part 2, A.3; *see also* Staff Surr., A.42.

- The TDR, on page 17, also identifies "(Ref. 2.21)" as the basis of the local buckling criterion. Reference 2.21, listed on page 5 of the TDR, is the "GE Letter Report, "Sandbed Local Thinning and Raising the Fixity Height Analyses (line Items 1 and 2 in Contract # PC-0391407)", dated December 11, 1992." Applicant's Ex. 39. AmerGen Surr., Part 2, A.3; *see also* Staff Surr., A.42.

- The GE Letter Report contains GE's analysis of what later became the local buckling criterion as shown in Applicant's Exhibit 11. AmerGen Surr., Part 2, A.3; *see also* Staff Surr., A.42.

- Finally, the pressure criterion is part of the CLB through the TDR-1108, p. 18 (Applicant's Exhibit 27), which establishes the required minimum thickness of 0.490" for "Very Local Wall (2½ Inch Diameter)." AmerGen Surr., Part 2, A.3.

5.18 On sur-rebuttal, Dr. Hausler testified that the GE Letter Report modeled only a "continuous area thinner than 0.736 inches per bay [that] was only 4.5 square feet, not 9 square feet. Therefore, . . . the maximum permissible contiguous area thinner than 0.736 inches in each bay should be less than 4.5 square feet." Citizens' Surr., A.4.

5.19 Dr. Mehta responded that Dr. Hausler misread the GE Letter Report when he interpreted that criterion to be half the size. Instead, due to symmetric conditions, the GE model addressed a locally thinned area of nine square feet, in the tray configuration identified in Applicant's Exhibit 11. *See* Tr. at 128 (Mehta). Under the GE model, and the local buckling acceptance criteria, there can be one locally thinned area, in such a configuration, in each of the ten sand bed bays. Tr. at 135-136 (Gallagher); *see* Tr. at 136-37 (Mehta). When asked whether taking into account symmetry in GE's modeling essentially meant that GE modeled an entire nine-square foot area, Dr. Hausler stated: "I can't answer that either affirmative or not affirmative. I don't know." Tr. at 80 (Hausler); *see also id.* at 168 (Hausler) ("I'm not really prepared to accept what's been said with respect to the [CLB] because I don't know anything to the contrary").

C. Conclusions

5.20 The CLB for purposes of license renewal is defined in 10 C.F.R. § 54.3, and includes NRC approvals as well as design basis information contained in a plant's Updated Final Safety Analysis Report ("UFSAR").

5.21 The Board finds that AmerGen's descriptions of the general buckling criterion, local buckling criterion, and pressure criterion are the acceptance criteria that are part of the OCNGS CLB, as documented in Sections 3.8.2.4, 3.8.2.5, 3.8.2.8, and 3.8.6 of the UFSAR and the accompanying references.

5.22 The Board agrees with Dr. Mehta that GE's analysis was symmetrical, so the 6" x 12" central square modeled in the GE Letter Report actually represents a 12" x 12" central square, and includes a tray in every bay.

5.23 Because the Board finds that the local buckling criterion is documented in the UFSAR and is part of the CLB pursuant to 10 C.F.R. § 54.3, the Board necessarily concludes that this criterion has not changed over time. The Board does not interpret AmerGen's use of more conservative, calculation-specific values to evaluate UT thickness data to have altered the CLB for the local buckling criterion.

VI. <u>AVAILABLE MARGIN</u>

6.1 The following section addresses the bounding remaining thickness of the OCNGS drywell shell in the sand bed region (*i.e.*, available margin). It starts with an introduction of the witnesses who provided the relevant testimony. It then discusses AmerGen's UT program, and concludes with an explanation of the parties' and the Board's conclusions regarding available margin and how it was calculated.

A. Witness Backgrounds

6.2 The discussion below regarding available margin is based on the testimony of five witnesses for AmerGen, four witnesses for the NRC Staff, and one witness for Citizens.

6.3 AmerGen's witnesses on this topic included Mr. Frederick W. Polaski, Dr. David Gary Harlow, Mr. Julien Abramovici, Mr. Peter Tamburro, and Mr. Martin E. McAllister. *See* AmerGen's Pre-filed Direct Testimony, Part 3: Available Margin ("AmerGen Dir., Part 3"); AmerGen. Reb. Part 3, A.1. Mr. Polaski's and Mr. Tamburro's background and qualifications are discussed above. Dr. Harlow is a Professor in the Mechanical Engineering and Mechanics Department at Lehigh University located in Bethlehem, Pennsylvania, and has 30 years of teaching and research experience in statistics, mechanical engineering, and corrosion engineering. AmerGen Dir., Part 3, A.1-A.3. Dr. Harlow has been an expert consultant for OCNGS, first in 1990, assisting Mr. Tamburro and others at the plant in preparing statistically-sound UT sampling plans for the upper and sand bed regions of the drywell shell, and later in 2006 reviewing the analysis and calculation of UT thickness measurement data collected from the sand bed region of the drywell shell during the 1992 and 2006 refueling outages prepared by AmerGen. *Id.* at A.4. Mr. Abramovici is a consultant with Enercon Services, Inc., located in Mt. Arlington, New Jersey, and was employed by GPUN, the former owner of OCNGS, from 1978-2000, as a mechanical engineer with extensive ASME code expertise. *Id.* at A.3. Most recently, Mr. Abramovici performed an independent design verification for Revision 2 of the "24 Calc.", Applicant's Exh. 16, which will be discussed further below. Mr. McAllister is an ASME Non-Destructive Examination ("NDE") Level III Inspector at OCNGS, and he supervised NDE activities for the drywell shell in the sand bed region during the 2006 refueling outage. *See* AmerGen Dir., Part 5, A.1-A.2;

6.4 The NRC Staff's witnesses were Dr. James A. Davis, Mr. Hansraj G. Ashar, Mr. Timothy O'Hara, and Mr. Arthur D. Salomon. The qualifications of these witnesses were discussed in Section V, above.

6.5 Citizens' witness was Dr. Hausler. Dr. Hausler's qualifications were provided in Section V, above.

B. AmerGen's Drywell Ultrasonic Testing Program

6.6 Buckling, due to the weight of the water and equipment on the drywell shell during an earthquake occurring during a refueling outage, is the bounding scenario for failure of the drywell shell in the sand bed region. *See* Applicant's Exh. 3, at 6-8; Applicant's Exh. 40, at 16. UT thickness measurements are taken to ensure that the drywell shell in the sand bed region meets applicable ASME Code criteria for buckling, as discussed in Section V, above.

6.7 AmerGen uses UT to measure the thickness of the drywell shell in the sandbed region. AmerGen Dir., Part 3, A.6. Some thickness measurements are taken from the interior, and some are taken from the exterior of the drywell shell. *Id.* It is obvious that the measured thickness represents the drywell shell thickness at the particular measurement point, regardless of whether the measurement is taken from the interior or exterior of the shell.

<u>Interior UT Measurements</u>

6.8 For purposes of AmerGen determining available margin, UT thickness measurements were taken from the interior of the drywell shell in the sand bed region during the 1992, 1994, 1996, and 2006 refueling outages. AmerGen Dir., Part 3, A.9.

6.9 These internal UT thickness measurements are taken in grids rather than as single points. AmerGen Dir., Part 3, A.10. Taking data in grids enables calculation of the average thickness of an area. *Id.* at A.11. It is possible to take grid data from the inside of the drywell because the surface is essentially flat. *Id.*

6.10 There are a total of nineteen internal grids, each of which is centered on or near the 11'3" elevation of the drywell shell. AmerGen Dir., Part 3, A.12. The internal concrete curb at elevation 11'0" prevents the grids from being placed at a lower elevation, except in two trenches that were excavated in the concrete in the 1980s. *Id.* The size and spacing of the internal grids are established by a metal template which is used each time UT measurements are taken. *Id.*

6.11 The locations for the internal UT measurements were selected in the mid-1980s, before there was access to the exterior sand bed region, by taking over 1,000 UT measurements to identify the thinnest "grid" locations for each bay. Tr. at 326 (Tamburro).

6.12 To ensure repeatability, there are permanent marks on the interior of the drywell shell that allow the metal template to be placed at the same location each time. AmerGen Dir., Part 3, A.13. Twelve of these grids are six inches square, each consisting of a total of forty-nine individual UT thickness measurement points. *Id.* at A.12. The remaining seven grids are rectangular—one inch by seven inches—using only the middle row of the same metal template. *Id.* Seven UT points are collected from each of these seven rectangular grids. *Id.* Also, there is at least one grid for each bay. *Id.*

6.13 Two acceptance criteria apply to these interior drywell grid data: the pressure criterion (where the thickness must be at least 0.490" over circular areas of diameters up to 2.5"), and the general buckling criterion with a uniform thickness for the entire drywell shell in the sand bed region of 0.736". AmerGen Dir., Part 3, A.14.

6.14 Because the thinnest average from any of the internal grids collected at any time (*i.e.*, 0.800" from grid 19A in 1992) is greater than the general buckling criterion, (*i.e.*, 0.736"), there is no need to compare the average grid measurements to the local buckling criterion (*i.e.*, 0.536"). AmerGen Dir., Part 3, A.15.

6.15 During the 2006 refueling outage, UT thickness measurements were taken from the two internal trenches,[112] one each in Bays 5 and 17, using the same 6" x 6" metal template of 49 points as was used for the interior grids centered at elevation 11'3". *See, e.g.*, Applicants' Exhibit 19, Attachment 1. Accordingly, the lowest elevation grid in Bay 17 spans approximately elevations 9'3" to 9"9". Tr. at 410 (Polaski). The average of the data from this lowest grid in the Bay 17 trench is 0.965". *Id.* at 406 (Polaski); Applicant's Exh. 19, Att. 1, at 8 of 10.

Exterior UT Measurements

6.16 During the 1992 and 2006 refueling outages, UT thickness measurements were taken from the exterior of the drywell shell in the sand bed region. AmerGen Dir., Part 3, A.16. Unlike the interior measurements, which are taken in grids, the exterior measurements are taken as single points. *Id.* at A.17.

6.17 Two of the important requirements for a UT probe to provide an accurate measurement are that the surface area being measured must be smooth over an area at least as large as the circular area of the UT probe, and that the UT probe needs to sit perpendicular to the surface of the metal it is measuring. AmerGen Dir., Part 3, A.18.

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[112] The trenches are described in paragraph 4.9, above.

6.18 The exterior surface of the drywell shell in the sand bed region that experienced historical corrosion has a very uneven surface, which prevents taking of UT data. AmerGen Dir., Part 3, A.18. This uneven surface was caused by corrosion that occurred before the exterior of the drywell shell in the sand bed region was cleaned and coated during the 1992 refueling outage with a multi-layer epoxy coating system. *Id.*

6.19 Prior to coating with epoxy, the metal at over one hundred individual points was ground to provide a smooth surface to allow the UT probe to sit perpendicular to the drywell shell surface. AmerGen Dir., Part 3, A.18. The areas were ground to about two inches in diameter. *Id.* External UT thickness measurement locations exist in all ten drywell bays. *Id.*

6.20 To be able to perform external UT measurements on a grid with 49 locations would require grinding much larger areas (6" by 6" or larger). AmerGen Dir., Part 3, A.18. Removing this metal would reduce the thickness of the drywell shell. *Id.* Therefore, a grid measurement approach was not used on the exterior. *Id.*

6.21 The exterior locations were identified on UT data sheets as being located at certain vertical and horizontal distances from the intersections of known welds. AmerGen Dir., Part 3, A.19. In 2006, AmerGen also marked some of these locations for even easier identification in the future. *See, e.g.*, Applicant's Exh. 29.

6.22 During the 1992 refueling outage, OCNGS took over 120 UT measurements. AmerGen Dir., Part 3, A.20. However, some of these measurements included two readings from the same location. *Id.* In addition, OCNGS took some single readings during that outage from the flat, essentially uncorroded exterior areas of the shell. *Id.* These specific locations could not be relocated during the 2006 refueling outage, *id.*, because there was no prepared area (*i.e.*, ground area) to indicate its location. Tr. at 196-97 (Polaski); *id.* at 439 (Hawkins). Accordingly, in 2006, single point measurements were taken from 106 of the previously-measured locations. AmerGen Dir., Part 3, A.20.

6.23 AmerGen compares the individual points to the various acceptance criteria. AmerGen Dir., Part 3, A.21. Single point measurements that are greater than 0.490" are deemed to meet the pressure criterion. *Id.* Single point measurements that are greater than 0.736" are deemed to meet the general buckling criterion. *See id.*

6.24 AmerGen compares multiple points that are thinner than 0.736" and that are in close proximity to each other, to the local buckling criterion (where the thickness must exceed 0.536" in the center of the tray configuration shown in Applicant's Exhibit 11). AmerGen Dir., Part 3, A.21. AmerGen also evaluates these multiple points based on their spatial relationship to each other, on their spatial relationship within the tray, and on their location within the bay. *Id.* For perspective, 23 of the 106 external readings in 2006 were less than 0.736." *Id.*

C. AmerGen's Position

6.25 AmerGen's position is that the bounding available margin for buckling at the start of the extended period of operations is 0.064". AmerGen Dir., Part 3, A.5, A.31. This is based on the thinnest average of the 49 UT thickness measurements from internal grid 19A, which in 1992 was 0.800", compared to the general buckling criterion of 0.736" (0.800"-0.736" = 0.064"). AmerGen Rebut., Part 3, A.26. AmerGen's evaluation of the internal UT grid data is documented in the "41 Calc.," which was submitted as Applicant's Ex. 20.

6.26 After determining that the data are normally distributed, AmerGen Dir., Part 3, A.24, AmerGen uses the average of the internal UT grid data (*i.e.*, the "sample average") to determine available margin. It does so because the sample average is what is important from a buckling perspective, not the individual points. AmerGen Rebut., Part 3, A.2 ("[B]uckling is not a phenomenon that is dependent on very local thickness, but instead on the average thickness over a larger area. Thus, the averages of these data, not the thinnest extremes, are representative of each grid"). Moreover, AmerGen argues that the nuclear industry standard is to use the sample average for determining available margin. *Id.* at A.54 (discussing average UT readings used for evaluating Degraded Piping, Erosion-Corrosion (FAC) Prone Piping, Pressure Vessel Shells, and Tanks).

6.27 AmerGen excludes certain UT data taken from the interior grids to calculate the average when those data are taken from points located over thicker metal plugs or when the data are otherwise outside the normal distribution. AmerGen Dir., Part 3, A.25. However, with one exception, including these data would have resulted in a higher (*i.e.*, thicker) average grid measurement. *Id.* The one point that would have resulted in a lower average grid measurement is not significant, as it would have changed the average grid reading from 1.122" to 1.088". *Id.*

6.28 In the Board's August 9, 2007 Order, we inquired into the "uncertainty" in the UT thickness measurements for both the internal and external data collected over time. "Uncertainty" refers to the level of assurance that a measurement is accurate. AmerGen Rebut., Part 3, A.5. This uncertainty can be biased in one direction, or "plus or minus," depending on how the uncertainty is created. For example, the UT technicians are competent and qualified but cannot locate the *exact* external measurement point each time; the accuracy of the UT equipment is excellent but still not 100%; and different technicians take the measurements in very slightly different ways. *Id.*

6.29 The only one-directional uncertainty for the internal UT data was believed to be due to grease that may not have been removed before UT measurements were taken during the 1996 refueling outage. AmerGen Rebut., Part 3, A.6(h). The grease would have resulted in UT measurements that were biased thick in 1996. *Id.* The only other uncertainty relevant here—instrument uncertainty—is not in one direction, but is plus or minus. *Id.* at A.6(a). AmerGen argues that averaging the internal data over 49 measurements makes these uncertainties insignificant because uncertainty "is negligible for sufficiently large numbers of measurements collected over time... [T]he more measurements you have . . . and the more times you collect those measurements, the less significant systematic error becomes." *Id.* at A.6-7.

6.30 The parties dispute how to interpret "reasonable assurance" under 10 C.F.R. § 54.29(a) with respect to evaluating UT thickness measurement data. AmerGen's position, as explained in the previous paragraph, is that the sample average is sufficient. As discussed below, Dr. Hausler believes that this evaluation must take into account 95% confidence limits. Citizens' Dir., A.16. AmerGen, however, claims that it does not ignore the 95% confidence interval. AmerGen Surr., Part 3, A.6. Rather, AmerGen calculates the lower 95% confidence interval of the sample average for each internal grid after each inspection to understand the variability of each calculated average. *Id.*; Applicant's Exh. 20 ("41 Calc."). The variability of the sample average demonstrates, however, that the calculated averages over time are well behaved and repeatable. AmerGen Surr., Part 3, A.6. There is an equal probability that the true mean is either greater or less than the calculated sample average within the 95% confidence interval, because the internal grid data are normally distributed. *Id.* Based on this calculation, and based on the Grand Standard Error calculation discussed in AmerGen's Rebut., Part 3, A.17, AmerGen concludes that the average is the best representation of the thickness over the inspected area. AmerGen Surr., Part 3, A.6.

6.31 AmerGen's evaluation of the external UT data is documented in the "24 Calc.," the most recent revision of which was submitted as Applicant's Exhibit 16. AmerGen Dir., Part

3, A.27. AmerGen developed the 24 Calc. to demonstrate compliance with the ASME Code, not to identify available margin. *Id.* at A.29. AmerGen applied a number of conservatisms in the 24 Calc. that would make it inappropriate, in AmerGen's opinion, to use that calculation to determine the actual available margin. *Id.* at A.30. With the application of such conservatisms, a determination can be made that actual thicknesses comply with ASME Code criteria, without determining the actual margin above the acceptance criteria.

6.32 AmerGen concludes, through Revision 2 of the 24 Calc., that all of the external points measured in 2006 meet the 0.536" local buckling criterion. Applicant's Exh. 16. And because the thinnest single UT thickness measurement is 0.602" in Bay 13, AmerGen concludes that the pressure criterion is easily satisfied. Tr. at 387 (Tamburro).

6.33 AmerGen treats the external UT measurement locations as biased thin compared to the rest of the drywell shell in the sand bed region. AmerGen relies on multiple forms of evidence that these locations are biased thin:

6.34 First, AmerGen quotes Applicant's Exhibit 27, at 16 (TDR-1108), which confirms that plant engineers had, in 1992, "a high level of confidence that we have identified the thinnest shell thickness for a bay." AmerGen Rebut., Part 3, A.42; Tr. 271-272 (Tamburro).

6.35 Second, AmerGen relies on a comparison of the external points to the internal UT grids as shown in Applicant's Exhibits 28 and 44, and as discussed in AmerGen's Rebuttal Testimony, Part 3, A.42, and during the hearing, Tr. at 272-274 (Tamburro), which show that there is thicker metal between or near these external points.

6.36 Third, AmerGen cites Dr. Hausler's own analysis discussed in Citizens' Exhibit 12, at 4: "the average outside measurements are significantly lower at comparable elevations [than the interior measurements]. This is probably because the choice of location for the external measurements was deliberately biased towards thin spots."

6.37 Fourth, AmerGen relies on depth micrometer readings that were taken at certain of the external UT points which demonstrate that the metal around these measurement points is thicker. Tr. at 329-330 (Tamburro and Polaski) (discussing Applicant's Exh. 16).

6.38 Finally, AmerGen relies on photos which show the external UT measurement locations as being thinner than their surroundings. Applicant's Exh. 29 (same as Applicant's Exh. 40, at 91) and Exh. 44; Tr. at 278 (Tamburro). Mr. Tamburro also personally observed what is shown on the photos for Bay 13. Tr. at 280, 328 (Tamburro).

6.39 AmerGen acknowledges that it is very difficult to find and replicate the exact external UT measurement point within the approximately 2-inch diameter prepared areas. Tr. at 305 (Hawkins). For example, UT readings taken even ¼-inch away from the official external measurement point can result in readings that are different by as much as 0.070". Applicant's Exh. 19, Att. 4, at 20 of 20 (Bay 19 data).

6.40 AmerGen also argues that corrosion of the exterior drywell shell surface has been arrested, as demonstrated by the averages of the grid data which have varied little over time since 1992. AmerGen Rebut., Part 3, A.38. Accordingly, AmerGen argues that there is no reason to believe that the available margin is being reduced.

D. Citizens' Position

6.41 Dr. Hausler argues that the bounding available margin needs to take into account 95% confidence limits. Citizens' Dir., A.16. According to Dr. Hausler, taking into account the 95% confidence limit of the internal UT grid data would result in an available margin of 0.034". He argues that AmerGen must subtract 0.030" from the measured average of 0.800" in grid 19A

(0.064" – 0.030" = 0.034") to account for uncertainty in the data and to take into account 95% confidence.

6.42 He derives the 0.034" value from an AmerGen response to an NRC Information Request, in which AmerGen agreed to take action if the future average of any of the internal grid data collected during an outage was +/- 0.021" different than previous readings. Citizens' Dir., A.16; Citizens' Exh. 10, at 2; Staff Exh. 1, at 3-121. This 0.021" value was based on one standard deviation of internal UT data of 0.011" plus uncertainty associated with instrument accuracy of 0.010". Citizens' Exh. 10, at 2.

6.43 Dr. Hausler argues that the 0.011" is based on only one standard deviation and that AmerGen is required to achieve two standard deviations, which is essentially equivalent to 95% of the distribution for normally distributed data. Citizens' Dir., A.12. To determine the lower 95% confidence interval for the data, he argues that AmerGen must subtract 0.030" from the available margin of 0.064", thus concluding that only 0.034" remains. *Id.* at A.16.

6.44 Although concluding that 0.34" remains at the bounding internal grid location (grid 19A), which is centered at elevation 11'3", Dr. Hausler testified that the most severe future corrosion, if any, would occur at the bottom of the former sand bed. Tr. at 50 (Hausler).

6.45 Dr. Hausler also believes that the internal UT grid data are not representative of the worst corrosion in each bay. *See generally* Citizens' Exh. 12, at 4 ("only the trench and outside measurements come close to represent [*sic*] the most severe corrosion at the highest elevations [of the sand bed region]"). For support, he plots the grid data from Bay 17 along with the trench and external data from the same bay. Citizens' Exh. 12, Figs. 3 and 4 (excluding data from grid 17D); Citizens' Exh. 61, Fig. 5 (including data from both grids 17A and 17D).

6.46 Dr. Hausler testified that the elevation that would have corresponded with a couple of inches below the top of the sand is representative of the worst overall corrosion on the exterior of the drywell shell. Tr. at 49 (Hausler). He identifies the internal grid from Bay 1, however, as a prime example of how the internal UT grids are located above this area of worst overall corrosion. Citizens' Exh. 39, at 15.

6.47 Dr. Hausler concludes that the external UT data points are representative of the drywell shell. *See, e.g.*, Citizens' Exh. 12, at 6 ("the measured points connect unless other measurements show this not to be the case"). He argues that the external points could not be the thinnest locations on the drywell shell for a number of reasons. First, it would be impossible for a person to visually identify the thinnest locations on the exterior because the sand bed region is difficult to maneuver in, and such identification cannot be done by eye. Tr. at 317-318 (Hausler). Second, he challenges the accuracy of the overlay of the internal and external points in Applicant's Exhibits 28 and 44, although he acknowledges that he did not evaluate the data supporting these exhibits. *See, e.g.*, Tr. at 312 (Hausler).[113] Finally, he points to "duplicate" and "triplicate" measurements that were taken in 2006 from some of the exterior UT locations. Tr. at 287-288 (Hausler).

6.48 Having concluded that it is acceptable to treat the external UT measurements as representative of the drywell shell in the sand bed region, Dr. Hausler prepared computer-generated contour plots interpolating the external UT data in Bays 1 and 13, (Citizens' Exh. 61, Figs. 1, 3), and then extrapolated the data in the same bays. *Id.*, Figs. 2, 4. The interpolation is

[113] During the hearing (Tr. at 553-562), we found that Citizens had access to the same underlying information regarding location of the internal and external UT data points as AmerGen because AmerGen produced that information through the mandatory disclosure process. Citizens' argument that they did not have the resources to translate that information, (Tr. at 555 (Webster) ("limited manpower")), was not persuasive. We denied Citizens' oral motion to require AmerGen to produce additional documents. Tr. at 559 (Judge Hawkens). We also denied Citizens' oral motion for reconsideration of that issue. *Id.* at 562 (Judge Hawkens).

based on triangulation, which calculates the average thickness between points. Tr. at 217 (Hausler). In addition, about half of the plotted points in Citizens' Exhibit 61, Figures 3 and 4, for Bay 13 are not actual data, because AmerGen did not take UT measurements for these points in 2006. Citizens' Exh. 61, at 13 (footnote). Instead, Dr. Hausler used the UT thickness measurements from 1992, but subtracted 0.020" from each measurement before feeding those measurements into the computer for plotting. *Id.*

6.49 Dr. Hausler uses these computer-generated contour plots to argue that there are locations that likely currently exceed the 0.536" local buckling criterion and the 0.490" pressure criterion. Tr. at 229, 320-322 (Hausler). Specifically, he interpolates the data from Bays 1 and 13 in an effort to demonstrate that there are "long grooves" of corrosion that are larger or are outside the geometric configuration of the local buckling criterion. Citizens' Dir., A.24; Citizens' Ex. 61, Figs. 1-4. He also extrapolates the data from these figures in an effort to demonstrate that there is a "finite probability" that the pressure criterion is exceeded. Tr. at 547 (Hausler). He arrives at these conclusions using extreme value statistics.[114] *See generally,* Citizens' Exh. 38 at 6-9; Tr. at 549-550 (Hausler). He concedes, however, that there are no actual UT thickness measurements that are less than 0.490". Tr. at 547-548 (Hausler).

6.50 Finally, Dr. Hausler argues that the uncertainty for each of the external UT measurements is 0.090". Citizens' Dir., A.15; Citizens' Exh. 13, at 8, 9. This uncertainty is not biased in one direction, but could be plus or minus. Tr. at 295-96 (Hausler). He derives 0.090" from the standard deviations for each bay, arriving at 0.03", 0.055" and 0.043" for the points in Bays 5, 15, and 19, respectively. Citizens' Exh. 13, at 3. He then "pools" these three values to arrive at 0.045" as a representative thickness for the sand bed region, but then doubles this value

[114] Extreme value theory is a branch of statistics dealing with the extreme observations, smallest and largest, from a sample. The general theory sets out to assess the type of probability distributions that characterize the smallest and largest of a population.

to account for the two standard deviations (*i.e.*, 95% confidence interval). *Id.*; Tr. at 288 (Hausler).

6.51 Dr. Hausler concedes that the current condition of the shell meets the 0.736" general buckling criterion. Tr. at 322 (Hausler).

E. NRC Staff's Position

6.52 The NRC Staff evaluated corrosion of the drywell shell as presented primarily in Sections 3.5 and 4.7.2 of AmerGen's License Renewal Application. Staff Dir., A.6. The Staff then sent Requests for Additional Information ("RAI") to AmerGen on various topics. *Id.* In March and April 2006, the Staff visited the plant and discussed some of these RAIs with AmerGen. *Id.* NRC Inspectors observed UT measurements taken during the 2006 refueling outage. *Id.*

6.53 The Staff also reviewed Revisions 0 and 1 to the "24 Calc." (Applicant's Exhs. 17 and 18) and the "11 Calc." (Applicant's Exh. 23). *Id.* The Staff did not review Revision 2 to the 24 Calc (Applicant's Exh. 16) because it was not available until after the issuance of the SER, and it was not submitted to the NRC for review in connection with the LRA. Staff Dir., at A.9.

6.54 The NRC Staff concurred with AmerGen on all the fundamental issues in this litigation. Mr. Ashar concurred that the external UT locations were biased thin, Staff Rebut., A.40 ("conservatively biased measurements"); *id.* at A.11 ("The UT measurements taken from outside the shell are not at random locations. They are taken at the locations judged to be the thinned areas"); Tr. at 285 (O'Hara) ("You can see the ground spots when you can find them, and you can see that there is an area around them that has thicker material than the spot itself").

6.55 Dr. Hartzman also concurred that corroded areas shown on Dr. Hausler's contour plots may be significantly overestimated. And Mr. O'Hara's visual observation of the external sand bed region in Bays 11 and 13 during the 2006 refueling outage, and review of the video and photographic records from the 1992, 1994 and 1996 refueling outages, did not support Dr. Hausler's findings of "long grooves." Staff Rebut., A.26.

6.56 Mr. O'Hara also testified that there is no requirement or industry practice for statistical analysis of UT data, rejecting Dr. Hausler's argument that the available margin ought to be determined with 95% confidence, or evaluated using extreme value statistics. Staff Rebut., A.10. Dr. Davis also testified that the industry practice is to use the average. Tr. at 287 (Davis).

F. Conclusions Regarding Whether the Acceptance Criteria Will Be Met at the Start of the Period of Extended Operation

6.57 The Board, as a threshold matter, first concludes that, based on the current condition of the drywell shell in the sand bed region, it expects the general buckling criterion to be met at the start of the period of extended operation. UT measurements taken between 1992 and 2006 from the interior grids demonstrate that the uniform thickness of the drywell shell in the sand bed region is now, on average, much greater than 0.736". *See* Applicant's Exh. 25 (table of UT grid data provided in response to Board Question # 9 in August 9 Memorandum and Order Ruling on Motions In Limine and Motion for Clarification (Aug. 9, 2007 (unpublished) ("August 9 Order"); Tr. at 181 (Hausler) ("the sand bed region is not corroded uniformly to .736"). These grid measurements are taken at an elevation (between 11'0" and 11'6") that generally corresponded with the top of the sand that was in the exterior sand bed region. And Dr. Hausler testified that this elevation, which is a couple of inches below the top of the sand bed in most bays, is representative of the worst overall corrosion on the exterior of the drywell shell. Tr. at 49 (Hausler). The Board notes (and AmerGen acknowledges) that the internal grid in Bay 1 is not representative of the corrosion in that bay. Tr. at 274 (Tamburro).

6.58 The Board next finds that the 0.490" pressure criterion is expected to be satisfied at the start of the period of extended operation for all actual UT thickness measurements. AmerGen has identified 0.602" in Bay 13 as the thinnest UT thickness measurement. Tr. at 387 (Tamburro). And Dr. Hausler testified that there are no actual measurements below 0.490". Tr. at 547, 548 (Hausler). Rather, Dr. Hausler believes that there is a "finite probability" that such a thinned location exists. *Id.* at 547. That finite probability, however, is based on an extrapolation of the data using extreme value statistics. *Id.* Although Citizens may have interpreted Question #10 of our August 9 Order to authorize them to submit an evaluation of AmerGen's external UT data using extreme value statistics, it was an impermissible interpretation for Citizens to then conclude that they could extrapolate from that data, which essentially fabricates data where none exist.

6.59 Finally, with respect to the 0.536" local buckling criterion, the Board also finds that this criterion is expected to be satisfied at the start of the period of extended operation. The best available data with which to compare to the local buckling criterion are the external UT data points. In 2006, only 23 of these points (out of 106) were below 0.736", so only these 23 points need to be evaluated using the local buckling criterion. AmerGen Dir., Part 3, A.21. The Board finds that the 24 Calc., Rev. 2 (Applicant's Exh. 16), adequately and conservatively addresses the local buckling criterion. Specifically, Applicant's Exhibit 16 addresses each of the 23 points and demonstrates why they meet the local buckling criterion, based on their spatial relationship to each other and thicker points, on their spatial relationship within the tray, and on their location within the bay.

6.60 Citizens' arguments that the applicable acceptance criteria are not currently met, and therefore will not be met at the start of the period of extended operation, are not persuasive.

Dr. Hausler's testimony is based on an assumption that the external UT data points are representative of the drywell shell. The Board finds, however, that AmerGen's evidence of historical documents, comparison of internal and external UT data, photos, and visual observations demonstrate that these UT locations are biased to produce thin results. Accordingly, Dr. Hausler's overall treatment of these data is inappropriate. More specifically, Dr. Hausler's contour plots and related analyses are based on the assumption that these external UT locations are selected at random, and therefore, are representative of the drywell shell as a whole. Dr. Hausler's contour plots also interpolate between data points and extrapolate beyond data points, which he acknowledges is the equivalent to speculating. Tr. at 259 (Hausler). Because the Board finds that the external UT locations were not selected at random, the Board necessarily finds that Dr. Hausler's contour plots and other analyses are not credible with respect to the existing or future condition of the drywell shell in the sand bed region.

G. Conclusions Regarding Available Margin

6.61 The Board finds that the available margin is greater than 0.200", which is significantly greater than the 0.064" margin very conservatively identified by AmerGen based on internal UT grid 19A, for the following reasons.

6.62 Dr. Hausler testified that the most severe future corrosion, if any, would occur at the bottom of the former sand bed. Tr. at 50 (Hausler). The exterior sand bed floor is located at approximately elevation 8'11". Tr. at 408 (Polaski). Internal UT grid 19A, however, is located near the top of the sand bed region because it is centered, along with all the other internal UT grids, at 11'3". AmerGen Dir., Part 3, A.12. Accordingly, the available margin from the internal grid locations is not bounding for a future corrosion scenario.

6.63 The Board finds that Bay 17 is representative of the severe corrosion that historically occurred in the sand bed region because it is among the bays with the least available margin (*i.e.*, 0.074") based on the internal UT grids centered on elevation 11'3". Applicant's Exh. 3, at 6-2 (Table 1).

6.64 The Board relies on the Bay 17 trench data to determine the available margin for the extended period of operation for the following reasons. The trench that was excavated in 1986 from the interior concrete floor in Bay 17 has its base at approximately elevation 9'3". Applicant's Exh. 28 (vertically to scale); Tr. at 407 (Polaski). The bottom of that trench is the lowest elevation from which AmerGen has UT grid data where the drywell shell is severely corroded. Tr. at 407 (Polaski).

6.65 The UT data from this trench were taken using the same 6" x 6" metal template of 49 points as the interior grids centered at elevation 11'3". Tr. at 406 (Polaski). Accordingly, the lowest elevation grid spans approximately elevations 9'3" to 9"9". *Id.* at 408, 410 (Polaski). The average of the data from this lowest grid in the Bay 17 trench is 0.965". *Id.* at 406 (Polaski); Applicant's Exh. 19, Att. 1, at 8 of 10.

6.66 Inherent in our findings above is the conclusion that it is reasonable for AmerGen to use the sample average and not the lower 95% confidence limit of the data or the mean. Citizens argue that the level of confidence must be 95%. *See, e.g.*, Citizens Dir., A.16. It is not clear what Citizens mean by 95%, as they define it in two, significantly different ways in their Rebuttal. AmerGen Surr., Part 3, A.3-4.

6.67 Dr. Hausler, however, admits that 95% (whatever its definition) is not the industry standard for determining available margin; rather he believes that it ought to be the standard. *See, e.g.*, Citizens' Exh. 38, at 8 ("there are currently no standards with respect to the certainty required"). And he provides no evidence that applicable nuclear industry Codes, guidance, or regulations require something other than the average.

6.68 In contrast, the NRC Staff and AmerGen have provided testimony that there is no requirement to use 95% confidence when determining available margin. Tr. at 287 (Davis); AmerGen Rebut., Part 3, A.54. The Board agrees with the NRC Staff and AmerGen on this point, because, as explained in Section III, above, there is nothing in the Atomic Energy Act or Commission practice or precedent brought to our attention that suggests that a 95% statistical confidence level is required to establish "reasonable assurance."

6.69 As for uncertainty applicable to the internal UT grid data, the Board finds that the only relevant uncertainty is UT instrument accuracy uncertainty. The Board agrees with AmerGen's experts that this uncertainty is essentially nullified by the averaging process. Accordingly, the Board does not require AmerGen to adjust its sample average for the internal UT grid data to account for instrument uncertainty.

6.70 The Board also finds that there are no relevant uncertainties for the internal UT grid data that are biased in only one direction, so the uncertainty associated with these data is nullified through averaging. The only unidirectional, biased uncertainty identified on the record was caused by grease that may have been left on the interior surface during UT measurements taken during the 1996 refueling outage. AmerGen Rebut., Part 3, A.6(h). The UT inspection protocol at that time did not specify the removal of the grease. *Id.* Accordingly, this uncertainty is historic only, and does not apply to any period of extended operation because "[t]he inspection procedures will clearly require that personnel conducting UT examinations remove the grease prior to performing the examination." AmerGen Dir., Part 3, A.39(h). And even it if did apply to the future, it would be applied to the 0.200" of available margin remaining at the base of the Bay 17 trench, and not internal UT grid 19A, for the reasons stated above.

6.71 As to the external UT, single-point data, the Board finds that the applicable uncertainties are UT instrument accuracy uncertainty and the uncertainty associated with finding the exact point within the approximately 2-inch diameter prepared areas. The uncertainty associated with finding the exact point dwarfs the UT instrument uncertainty in significance because UT readings taken even ¼-inch away from the official external measurement point can result in readings that are different by as much as 0.070". Applicant's Ex. 19, Att. 4, at 20 of 20 (Bay 19 data). Accordingly, there is no meaningful way to adjust the external UT data points to account for uncertainty. Rather, they should be treated for what they are: individual points that are representative of biased thin points in the shell. As such, these points cannot be used to determine available margin, although they are quite useful to ensure that the shell meets the ASME Code through the local buckling criterion and the pressure criterion.

VII. POTENTIAL SOURCES OF WATER

7.1 This Section discusses potential sources of water that, in the absence of mitigative measures, could come in contact with the external sand bed region of the drywell shell. It begins with an introduction of the witnesses who provided the relevant testimony. Next, historical sources of water and corrective actions are discussed. Finally, AmerGen's commitments to future actions to preclude leakage of water into the external sand bed region of the drywell shell are summarized. At the hearing, the Board inquired into the potential that water could come into contact with the external sand bed region of the drywell shell because, in the absence of such water, no further corrosion of that external surface during the period of extended operation is possible.

A. Witness Backgrounds

7.2 AmerGen's witnesses on this topic included Mr. John F. O'Rourke, Mr. Ahmed Ouaou, Mr. Francis H. Ray, Mr. Jon C. Hawkins, and Mr. Scott R. Erickson. Mr. O'Rourke and Mr. Ouaou's qualifications were previously described. Mr. Ray is the Engineering Programs Manager at OCNGS. AmerGen Dir., Part 4, A.1. Mr. Hawkins is an ASME Non-Destructive Examination ("NDE") Level III Inspector, employed at Exelon's Peach Bottom Atomic Power Station. *Id.* Mr. Erickson also is an ASME Non-Destructive Examination ("NDE") Level III Inspector. *Id.* He is employed by Sonic Systems International, under contract with General Electric Corporation, providing engineering services at nuclear power plants. *Id.*

7.3 Mr. Hansraj Ashar, Dr. James Davis, and Mr. Timothy O'Hara testified for the NRC Staff. Their qualifications were previously described.

7.4 Dr. Rudolf Hausler testified for Citizens. His qualifications were previously described.

B. Known Sources of Water in the Sand Bed Region and Corrective Actions Taken

7.5 Historically, defects in the reactor cavity liner at OCNGS allowed water to leak behind the liner and run down into the reactor cavity concrete trough. AmerGen Dir. Part 4, A.5. If the flow rate from these defects exceeded the capacity of the two-inch trough drain line, or if the trough was damaged or blocked, then water would back up into the drywell expansion gap and flow by gravity to the outside of the drywell shell and into the exterior sand bed region, approximately 80 feet below. *Id.* Historically, this water was held against the drywell shell by the sand in the sand bed region prior to the removal of the sand during the 1992 refueling outage. Tr. at 413 (O'Rourke).

7.6 The reactor cavity is only filled with water during refueling outages and during those other rare outages when the reactor vessel must be opened. AmerGen Dir., Part 4, A.6. Thus, leakage from the reactor cavity liner is only possible during these outages, and not during normal operations. *Id.*; *see* also Tr. at 414 (O'Rourke). The refueling cycle is once every two years. *Id.* The testimony at the hearing indicated that, even if there was future leakage during refueling outages, such leakage would likely be restricted to less than 26 days every two years. Tr. at 414 (O'Rourke), *see id.* at 417 (Ray). This is important to the determination of potential future corrosion rates. As noted above, forced outages where the reactor cavity is filled with water are rare, likely very limited in duration, and OCNGS has not experienced such an outage since at least 1990. AmerGen Dir., Part 4, A.6; *see also* Tr. at 414-417 (O'Rourke).[115]

7.7 During the 1980s, non-destructive examinations revealed through-wall and surface defects near weld joints in the reactor cavity liner. AmerGen Dir., Part 4, A.7. The reactor cavity liner is shown in Applicant's Exhibit 9. *Id.*

7.8 To address the defects in the reactor cavity liner, OCNGS chose to use metal tape and strippable coating as an effective, practical option to minimize leakage when the cavity is filled with water. AmerGen Dir., Part 4, A.8. The previous owner also repaired damage to the reactor cavity concrete trough, shown in Applicant's Exhibit 8, to minimize the possibility of water escaping the trough and entering the area between the concrete shield wall and exterior drywell shell. *Id.* At the hearing, AmerGen's Vice President for License Renewal, Mr. Gallagher, testified that, since the corrective actions taken in the 1990's, there is no current source of water leakage into the sand bed region during refueling outages. Tr. at 109-110, 112 (Gallagher). Citizens' expert, Dr. Hausler, did not suggest that there was any other source of

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[115] AmerGen did not review records prior to 1990 to determine if such forced outages had occurred before then, but such outages are rare, occurring perhaps once or twice over the lifetime of a plant. Tr. at 415 (O'Rourke).

water that could leak into the sand bed region other than the reactor cavity (also sometimes referred to as the "refueling" cavity.) Tr. at 411-412, 423 (Hausler). He also acknowledged that he did not believe that "condensation on the outside [of the drywell shell] is really a source of water that we might have to worry about." Tr. at 412 (Hausler).

7.9 The use of metal tape and strippable coating, when the reactor cavity is filled with water, has been effective and has drastically reduced the amount of reactor cavity liner leakage. AmerGen Dir., Part 4, A.8. During the 2006 refueling outage, observation of the reactor cavity liner leakage revealed a leak rate of approximately 1 gallon per minute. *Id.* This level is well within the capacity of the reactor cavity trough drain system, which is estimated using standard hydraulic principles to be approximately 50 gallons per minute. *Id.* The trough drain system directs this small amount of leakage into the controlled drainage collection system, so that it does not reach the exterior drywell shell. *Id.*

7.10 Currently no water reaches the exterior sand bed region during refueling outages because: (1) metal tape and strippable coating were used during the 2006 refueling outage; and (2) the trough drain is not blocked. AmerGen Dir., Part 4, A.10. No water was observed on the exterior of the drywell shell in the sand bed region. *Id.* Further, daily inspections from the Torus Room during the 2006 outage identified no evidence of water leakage from the sand bed drains. *Id.*; Applicant's Exh. 55. AmerGen made a formal commitment to the NRC to apply the strippable coating to the reactor cavity during every refueling outage. Applicant's Exh. 10, Encl. at 2. In its prefiled testimony, AmerGen Surr., Part 1, A.4, and in testimony at the hearing, Tr. at 421-422 (O'Rourke), AmerGen confirmed that its commitment extended to any other outage in which the reactor cavity would have to be filled with water, however rare that occurrence might be. The NRC Staff witnesses concurred with this designation of the scope of AmerGen's commitment. Tr. at 422 (Ashar). Dr. Hausler had no concerns about AmerGen's commitment as it related to non-refueling outages. Tr. at 63 (Hausler).

7.11 Trained NDE personnel entered the external sand bed region during the 2006 refueling outage as part of their inspections of the external surface of the drywell shell and confirmed that there was no water present. AmerGen Dir., Part 4, A.11.

7.12 In 2006 AmerGen addressed evidence that water had been in the sand bed region during prior refueling outages. AmerGen Dir., Part 4, A.12. This evidence was consistent with the failure to apply strippable coating during certain past refueling outages. *Id.* For example, there were a number of white discolorations, up to approximately 3-4 feet in diameter, on the concrete floor near some of the sand bed drains that appeared to be the residue left behind by water. *Id.*

7.13 Earlier in 2006, AmerGen identified water in three of the five plastic bottles in the Torus Room that collect water from the sand bed drains. AmerGen Dir., Part 4, A.12. Two of the bottles were found nearly full. *Id.* AmerGen concluded that the water in these bottles was old because the plastic drain lines from the sand bed drains were dry and there was no water on the Torus Room floor. *Id.*

7.14 Extensive investigations of a large number of other plant components in the late 1980s and early 1990s confirmed that the source of historical leakage onto the exterior drywell shell was the reactor cavity liner. AmerGen Dir., Part 4, A.13. The plant components considered as potential sources of leakage were: the bellows seal at the bottom of the reactor cavity (as shown in Applicant's Exhibit 8), the reactor cavity drain line, the refueling cavity metal trough and its associated gasket (also as shown in Applicant's Exhibit 8), the concrete trough located below the metal trough, the reactor cavity steps, the equipment pool and reactor cavity skimmer systems, the equipment pool liner, drain, and support pad, the spent fuel pool liner, and piping buried in concrete. *Id.* The licensee's investigations eliminated these components as known sources of water. Again, when asked at the hearing, Citizens' witness, Dr. Hausler, did not suggest that any of these remain as leak sources to the sand bed region. Tr. at 423 (Hausler).

7.15 Although Dr. Hausler has now testified that condensation on the exterior surface is not credible, Tr. at 412, we independently reach the same conclusion, for the following reasons. Condensation will not occur unless the drywell shell is cooler than the surrounding air. AmerGen Dir., Part 4, A.14. The temperature gradient across the drywell shell during normal operations runs from the hotter drywell interior to the cooler external sand bed region, because the reactor pressure vessel and other equipment located inside the drywell generate a significant amount of heat. *Id.* The components heat the nitrogen-inerted environment inside the drywell during operations, which, in turn, heats the drywell shell to temperatures significantly above the Reactor Building ambient temperature. *Id.* This temperature differential prevents condensation from forming on the exterior of the drywell shell in the sand bed region. *Id.*

7.16 During the first few days of an outage, there remains a temperature differential between the drywell shell and the ambient air in the Reactor Building, preventing condensation during this period. AmerGen Dir., Part 4, A.15. However, if the drywell chillers are used to cool the drywell interior, then it is theoretically possible for the drywell shell temperature to drop below the ambient Reactor Building air temperature. *Id.* Chillers are used during refueling outages and other outages when extended access to the drywell is required. *Id.* If condensation were to occur, however, then such postulated condensation would only last until restart, when the drywell shell temperature would rise and any water would evaporate. *Id.* Thus, such postulated water would only remain for the duration of the outage. *Id.*

7.17 During the 2006 refueling outage, qualified NDE visual inspectors examined each individual bay outage and found no evidence of condensation on the exterior of the drywell shell in the sand bed region. AmerGen Dir., Part 4, A.16.

7.18 At the hearing, in response to a direct Board inquiry, Dr. Hausler provided no evidence that there was a source of water, other than the reactor cavity, that could result in leakage into the sand bed region. Tr. at 422-423 (Hausler).

C. AmerGen's Commitments Related to Control of Water Leakage

7.19 AmerGen has committed to perform future actions to prevent water leakage into the sand bed region. *See* AmerGen Dir., Part 1, A.27.

7.20 AmerGen will verify that the reactor cavity seal leakage concrete trough drain is clear from blockage once per refueling cycle. AmerGen Dir., Part 1, A.27. Any identified issues will be addressed via the OCNGS corrective action process. *Id.*

7.21 The reactor cavity seal leakage concrete trough drains and the drywell sand bed region drains will be monitored for leakage.

- The sand bed region drains will be monitored daily during refueling outages. If leakage is detected, procedures will be in place to determine the source of leakage and investigate and address the impact of leakage on the drywell shell, including verification of the condition of the drywell shell coating and moisture barrier (seal) in the sand bed region. UTs will also be performed on any areas in the sand bed region where visual inspection indicates that the coating is damaged and corrosion has occurred. UT results will be evaluated per the existing program. Any degraded coating or moisture barrier will be repaired. These actions will be completed prior to exiting the associated outage.

- The sand bed drains also will be monitored quarterly during the plant operating cycle. If leakage is identified, the source of water will be investigated and corrective actions taken or planned as appropriate. In addition, if leakage is detected, the following items will be performed during the next refueling outage:

   - Inspection of the drywell shell coating and exterior moisture barrier (seal) in the affected bays in the sand bed region;
   - UTs will be performed on any areas in the sand bed region where visual inspection indicates that the coating is damaged and corrosion has occurred; and
   - UT results will be evaluated per the current program

- Any degraded coating or moisture barrier will be repaired.

AmerGen Dir., Part 1, A.27.

7.22 A strippable coating will be applied to the reactor cavity liner to prevent water intrusion into the gap between the drywell shield wall and the drywell shell during periods when the reactor cavity is flooded. AmerGen Dir., Part 1, A.27.

7.23 The NRC Staff also summarized AmerGen's commitments related to this subject. *See* Staff Dir., A.12.

7.24 As described in Finding 4.20, above, as a condition of the renewed license, AmerGen will be required to make an additional commitment to periodically inspect the sand bed drains for blockage, consistent with its existing internal procedures.

7.25 Based on the above, the Board concludes that leakage from the reactor cavity is the only known potential source of water on the exterior of the drywell shell in the sand bed region and that AmerGen's commitments effectively eliminate the potential for water leakage from the refueling cavity onto the drywell shell exterior, during the only time when the reactor cavity is filled with water; *i.e.*, during refueling outages or other outages where the reactor cavity may need to be filled with water. The Board further finds that condensation on the exterior of the drywell shell in the sand bed region during normal operations is not credible, because the drywell and drywell shell are the heat source, the Reactor Building ambient air is the heat sink, and there is no potential for condensation during outages.

7.26 In the absence of such water, there is reasonable assurance that no further corrosion of the sand bed region will occur during the period of extended operations. On that basis alone, the Board can and does find that AmerGen's 4 year UT frequency is adequate and that there is reasonable assurance that the CLB will be maintained for the period of extended operation.

7.27 However, should water reach the external sand bed region, we conclude that it will be detected through monitoring of the sand bed drains which is performed daily during outages when the reactor cavity is filed with water, and quarterly during normal operations. Any water that is found will trigger the additional commitments listed above, which we find adequate.

VIII. EPOXY COATING

8.1 This Section addresses the epoxy coating system that protects the OCNGS exterior drywell shell in the sand bed region. Again, it begins with an introduction of the witnesses who provided the relevant testimony. Next, the epoxy coating system itself is described in detail, followed by an overview of the expected life of the coating and how it is expected to eventually degrade. Finally, this Section concludes that the coating has arrested corrosion in the sand bed region, and can be expected to preclude further corrosion of the exterior shell in the sand bed region during the period of extended operation.

A. Witness Backgrounds

8.2 The information presented below regarding the drywell shell epoxy coating is based on the testimony of five witnesses for AmerGen, three witnesses for the NRC Staff, and one witness for Citizens.

8.3 AmerGen's witnesses on this topic included Mr. Jon R. Cavallo, Mr. Martin E. McAllister, Mr. Scott R. Erickson, and Mr. Ahmed Ouaou. The qualifications of Mr. McAllister, Mr. Erickson and Mr. Ouaou have been previously described. Mr. Cavallo is Vice President of Corrosion Control Consultants and Labs, Inc., where he provides corrosion mitigation professional engineering services in surface preparation, protective coatings and linings. AmerGen Dir., Part 5, A.1-2. He has worked on coatings and corrosion control at nuclear power facilities for over 35 years, contributed to a variety of Electric Power Research Institute ("EPRI") Reports on coatings-related topics, and is active in a number of national technical societies including SSPC, NACE and ASTM. *Id.* at A.3.

8.4 Mr. Hansraj Ashar, Dr. James Davis, and Mr. Timothy O'Hara testified for the NRC Staff. Their qualifications were previously described. With respect to coatings, Dr. Davis has worked on coatings and corrosion control since 1968, and has worked on coatings issues at nuclear facilities for the past 16 years at the NRC. Staff Dir. A.2(b).

8.5 Dr. Hausler testified with respect to the epoxy coating system for Citizens. Dr. Hausler's general background and qualifications are discussed in Section V, above. With respect to coatings, Dr. Hausler's expertise appears to be primarily in thin-film modified phenolic coatings used in high-temperature and high-pressure gas production environments, which typically involve highly corrosive pressurized fluids, corrosive gases, and continuous fluid flow. AmerGen Reb., Part 5, A.5; *see also* Citizens' Exh. D. None of these conditions are present in the OCNGS sand bed region. AmerGen Rebut., Part 5, A.5. At the evidentiary hearing, Dr. Hausler acknowledged that he was unfamiliar with the composition of the epoxy coating system used in the OCNGS sand bed region (Tr. at 459 (Hausler)), even though the specifications were submitted as Applicant's Exhibit 35.

8.6 Due to his acknowledged lack of direct experience in the specific coating system used in the sand bed region and the operating environment this coating system is exposed to, when Dr. Hausler's testimony on the epoxy coating system conflicts with that of the witnesses for AmerGen and the Staff, Dr. Hausler's testimony will be given less weight than that of other witnesses.

B. The Epoxy Coating System

8.7 AmerGen's Direct Testimony, Part 5, A.6, describes the OCNGS drywell shell epoxy coating system. It was applied during the 1992 refueling outage. It is a 100% solids, three-layer epoxy coating system that includes one pre-prime and two additional coats. The Devoe "Pre-Prime 167 Rust-Penetrating Sealer" is an epoxy coating that soaks and penetrates into the semi-irregular surface of the steel substrate and promotes coating system adhesion. It is recommended by the manufacturer for use in areas where, due to restrictions or economics, blasting or a thorough hand cleaning of the substrate may not be feasible. The two additional coats are comprised of a Devran-184 epoxy. The pre-prime is clear, and the middle and top coats have contrasting pigments, with the top coat a grey-ish white color. This pigment contrast was chosen to ensure continuous and adequate coverage and for easy detection of signs of deterioration. The Devran epoxy coating system is designed for coating tank bottoms, including water tanks, fuel tanks, and selected chemical tanks.

C. Application of the Epoxy Coating System

8.8 Citizens presented testimony on the potential for small defects in the epoxy coating system, known as pinholes or holidays, which Dr. Hausler alleged were "always" present and that these defects "can provide sites for corrosion to develop." Citizens' Dir., Att. 5, at 16. Because OCNGS did not perform electrical conductivity testing of the installed epoxy coating, Dr. Hausler believes that "it is likely that there were at least some pinholes on the coating from the start." *Id.*; *see also* Citizens' Exh. 39, at 17 (suggesting that the epoxy coating system should have been tested for pinholes or holidays using a wet sponge technique); Tr. at 447 (Hausler) (OCNGS personnel "haven't looked" for pinholes or holidays).

8.9 AmerGen's primary expert on this topic, Mr. Cavallo, and Dr. Davis for the Staff agreed with Dr. Hausler that pinholes or holidays are very localized defects in a coating that can be created during the original application of a coating, as a result of problems such as failure to properly cure the coating. AmerGen Dir., Part 5, A.14; Staff Dir., A.14. As such, pinholes and holidays are not defects that are caused by degradation of the coating over time. AmerGen Dir., Part 5, A.13; *see* Staff Dir., A.14.

8.10 Dr. Davis and Mr. Cavallo further testified that since pinholes and holidays occur during the application process, the three-layer system chosen by OCNGS, and the techniques and tools used in the application, make it unlikely that such pinholes or holidays would extend through the three layers to expose the underlying metal substrate. AmerGen Dir., Part 5, A.14; Staff Dir., A.14.

8.11 Mr. Cavallo further testified that, if pinholes or holidays have existed since the coating was applied during the 1992 refueling outage, and water was reported to be present in the external sand bed region when strippable coating was not used on the reactor cavity liner during the 1994 and 1996 refueling outages, (AmerGen Dir., Part 5, A.14), the corrosion that would have resulted from that water entering pinholes or holidays would be visible today due to the volume of corrosion products (iron oxides) and surface rust staining caused by the corrosion process. *Id.*; *see also* AmerGen Rebut., Part 5, A.10; Tr. at 447-48 (Cavallo).

8.12 The trained NDE inspectors, Mr. Hawkins and Mr. Erickson, testified both in their pre-filed testimony and at the hearing that during the 2006 refueling outage they did not observe any evidence of corrosion products caused by corrosion, such as could occur at the site of pinholes or holidays. AmerGen Dir., Part 5, A.11, A.23; Tr. at 448 (Hawkins, Erickson).

8.13 In rebuttal testimony, Mr. Cavallo also pointed out that, under National Association of Corrosion Engineers ("NACE") standards, the wet sponge technique to detect pinholes and holidays suggested by Dr. Hausler is not required for a coating in atmospheric service (such as the OCNGS drywell epoxy coating system), and is intended for more aggressive, immersion service. AmerGen Surr., Part 5, A.3. Citizens did not respond to this evidence.

8.14 Citizens have presented no evidence that pinholes or holidays exist in the coating system, or that the methods and testing used in the application of the coating were deficient such that pinholes or holidays would be expected. If such defects existed, then evidence of the resulting corrosion would have been visible during the 2006 refueling outage, but no such evidence was identified. Moreover, the Board finds no evidence to suggest that such localized defects could be significant from a buckling perspective, which, as described in Finding 6.6, above, is the bounding scenario for determining the available margin against future corrosion.

8.15 In rebuttal, Citizens presented two exhibits, which, Dr. Hausler alleged, showed that "areas of the shell in the sandbed region were not coated with epoxy because they are inaccessible." Citizens Rebut. A.18 (citing Citizens' Exhs. 40-41). Citizens' Exhibit 40 was a November 2006 AmerGen e-mail discussing the *possibility* that parts of the sand bed region were not coated: "[a]ssuming there are areas that could not be accessed and/or protective coating applied . . ." Citizens' Exh. 40. Citizens' Exhibit 41 was an OCNGS evaluation written *before* the sand was removed and the coating applied. AmerGen Surr., Part 5, A.6.

8.16 On sur-rebuttal, AmerGen responded by pointing out that the documents cited by Citizens did not actually provide any evidence that any portion of the sand bed region was uncoated. AmerGen Surr., Part 5, A.6. At the hearing, Mr. Hawkins and Mr. O'Hara both testified that they had been in the sand bed region during the 2006 refueling outage, and had observed that the drywell shell in the sand bed region was "completely coated" (Tr. at 444 (O'Hara)), "from the floor up the drywell shell . . . much higher than the [top of the sand bed region]." Tr. at 437 (Hawkins).

8.17 Based on the above, the Board concludes that the drywell shell in the sand bed region is completely coated by an epoxy coating system that has arrested the corrosion that had historically occurred. Citizens have presented no evidence to the contrary.

D. Expected Life of the Epoxy Coating System

8.18 Mr. Cavallo testified that the epoxy coating system is in a relatively benign environment in terms of exposure to radiation, elevated temperature, submersion in water, mechanical damage, and ultraviolet ("UV") light. AmerGen Dir., Part 5, A.7. The estimated total radiation dose over the expected lifetime of the coating, including the period of extended operation, would be orders of magnitude smaller than the dose that would be expected to cause a failure of the epoxy coating system. *Id.* Similarly, the temperatures expected in the sand bed region would not be expected to exceed 139° F, while the epoxy coating system is rated for 250° F, and is not subjected to submersion in water. *Id.* Finally, no mechanical damage or exposure to UV light is expected. *Id.* Thus, none of the factors that would be most likely to contribute to deterioration of the coating over time are present. *Id.* While some defects, resulting from application errors, may take place in the "early years after initial application . . . an extended period, on the order of decades" follows where no deterioration is expected. *Id.* at A.9. As a result, Mr. Cavallo's opinion was that the epoxy coating system should last for the life of the plant, including the period of extended operation, provided that proper inspections are conducted and, in the unlikely event that defects are identified, necessary corrective maintenance would be performed to restore the system such that it would continue to ensure performance of the drywell's intended function. *See id.* at A.7.

8.19 The coating was nearly 14 years old when it was inspected during the October 2006 refueling outage, and it remains in excellent condition, as reported by those who performed the VT-1 visual inspections during that refueling outage. AmerGen Dir., Part 5, A.8; *see also* Tr. at 448 (Hawkins, Erickson).

8.20 On direct, Dr. Hausler relied upon prior testimony from Mr. Ouaou before the Advisory Committee on Reactor Safeguards ("ACRS"), that the lifespan of the coating has been estimated at anything from ten to twenty years. Citizens Dir., A.21. Thus, Dr. Hausler concluded that "it is not reasonable to assume that the coating will not fail during any period of extended operation." *Id.*

8.21 In rebuttal, Mr. Ouaou clarified his testimony before the ACRS. The quoted estimates of a ten- to twenty-year lifetime were conservative judgments by OCNGS personnel at the time of installation, but as he testified before the ACRS, additional research, including discussions with the vendor, led him to the conclusion that the lifetime of the coating was not so limited. AmerGen Rebut. Part 5, A.8; *see also* Tr. at 456-57 (Ouaou).

8.22 On rebuttal, Dr. Davis concurred with Mr. Cavallo that poorly or improperly applied coatings tend to fail early in life, while coatings applied to surfaces that are properly prepared and coatings that are properly applied can survive for many years. Staff Rebut., A.35; *see also* Tr. at 457-58 (Davis). In Dr. Davis' opinion, the fact that visual inspections have determined that the OCNGS coating system is in very good condition after 15 years of service, indicates that the surface was properly prepared and that the coatings were properly applied. Staff Rebut., A.35. Dr. Davis also concurred that the epoxy coating system was not exposed to many of the stressors that may shorten the life of coatings, such as exposure to ultraviolet light, mechanical damage, high radiation, high temperature, and continuous moisture. *Id.*

8.23 In rebuttal, Mr. Cavallo testified that the use of visual inspections to detect coating failures is based on established industry practice. AmerGen Rebut., Part 5, A.6. ASME Section XI, Subsection IWE is mandated by 10 C.F.R. § 50.55a, recognizes that containments are coated, and requires a visual inspection of the coating to identify ongoing corrosion of the containment vessel under the coating. *Id.* Also, the NRC has endorsed these practices in the GALL Report (NUREG-1801, Vol. 2, Appendix xi.S8). *Id.* Therefore, VT-1 inspections performed by qualified inspection personnel are the ASME Code-approved means of assessing the condition of a coating system. *Id.*

8.24 Dr. Hausler's rebuttal testimony indicated that the epoxy coating system is susceptible to "spontaneous" and "rapid" failure that might not be detected by visual inspections before significant deterioration took place. *E.g.* Citizens' Exh. 39, at 17. In Dr. Hausler's opinion, contributing factors to such failures include "constant vibration and fatigue and elevated temperatures." *Id.*

8.25 In response to our questions at the hearing, Mr. Cavallo and Dr. Davis testified that, if the coating system were to deteriorate, they would expect to see rust "staining" to develop over a "period of three or four years," *i.e.* the interval between visual inspections of the coating, before more significant signs of coating failure and corrosion such as carbuncles appeared. Tr. at 452 (Cavallo, Davis). Mr. Ouaou testified that he had no information from the vendor that would lead him to believe that there would be relatively rapid deterioration of the coating between inspections. Tr. at 457 (Ouaou).

8.26 Dr. Hausler responded that "elevated" temperatures, above "about 150 degrees" Fahrenheit might still cause such rapid coating failure. Tr. at 458 (Hausler). Mr. Cavallo, however, pointed out that the epoxy coating system is designed for continuous exposure to temperatures up to 250° F, and that the temperatures in the sand bed region are not expected to even approach 150° F. Tr. at 465-66 (Cavallo).

8.27 The Board is not convinced by Dr. Hausler's speculation that elevated temperatures or other environmental factors could lead to rapid failure of the epoxy coating system. Based on uncontroverted testimony from AmerGen's witnesses, the Board concludes that the temperatures that Dr. Hausler indicated would be required to cause such failure simply are not present in the sand bed region, nor are there any other environmental conditions that would be expected to degrade the epoxy coating system. Thus, the Board concludes that there is no reason to believe that the epoxy coating system would quickly and unexpectedly fail and leave the drywell shell susceptible to rapid, undetected corrosion.

E. The Epoxy Coating System Remains in Excellent Condition

8.28 Mr. McAllister's and Mr. Hawkin's direct testimony stated that AmerGen's protective coating monitoring program includes VT-1 visual inspections of the epoxy coating system by qualified inspectors in accordance with ASME Section XI, Subsection IWE. AmerGen's Dir., Part 5, A.12. Under the VT-1 method, trained and qualified individuals inspect surfaces such as the drywell shell for evidence of flaking, blistering, peeling, discoloration, and other signs of degradation that would be early signs of potential coating failure. *Id.* The VT-1 technique is used throughout the nuclear industry, and is designed to be used on any type of steel or concrete surface, including irregular surfaces. *Id.*

8.29 Mr. Cavallo and Dr. Davis both testified that, as carbon steel corrodes, the reaction between the oxygenated water and the iron in the steel results in iron oxide products that can occupy a volume many times greater than the volume of the underlying corroded steel. AmerGen Dir., Part 5, A.15; Staff Dir., A.15. If corrosion were to take place at a pinhole, then the amount of localized corrosion would, in a four-year period, generate an irregularly-shaped roughly hemispheric deformation called a "carbuncle" and corrosion products would seep out through the postulated pinhole or holiday onto the light gray epoxy coating surface. AmerGen Dir., Part 5, A.15; *see also* Staff Dir., A.15. Any corrosion products that seep out onto the coated exterior of the drywell shell from a pinhole or holiday would be clearly visible during a VT-1 inspection and would be visible to an inspector performing a VT-1 inspection. AmerGen Dir., Part 5, A.15

8.30 The epoxy coating system on all 10 bays of the OCNGS drywell shell was inspected in 2006 by NDE Level II or III inspectors using the VT-1 method, and no recordable indications were found. AmerGen Dir., Part 5, A.11. The results of those inspections, submitted as AmerGen's Exhibit 24, show that the epoxy coating system is still in excellent condition, with no flaking, chipping, blistering, peeling, pinpoint rusting, cracking, chalking or discoloration, or any evidence of corrosion or corrosion products from the exterior drywell shell in the sand bed region identified by the inspectors. *Id.* at A.23. Likewise, no gaps or failure to coat any portion of the sand bed region were identified. *Id.* Instead, there was a visible shine indicative of a coating in pristine condition. *Id.*

8.31 At the hearing, Dr. Hausler identified a photograph in AmerGen's Exhibit 40, page 91, that he stated as appearing to be "corroded or is full of corrosion products . . . ." Tr. at 441 (Hausler). The picture did depict the epoxy coating in the sand bed region, but also depicted other plant structures. *See* Tr. at 442-45 (Hawkins, Tamburro, O'Hara). As the testimony of Mr. Hawkins, Mr. Tamburro, and Mr. O'Hara made clear, although the feature described by Dr. Hausler in the photograph was difficult to clearly identify, it was not part of the drywell shell. *Id.* Further, all three of these individuals had entered the sand bed region during the 2006 refueling outage and found the shell entirely coated in the sand bed region, with no such corrosion products. *Id.* (Hawkins, Tamburro, O'Hara). Citizens presented no other evidence suggesting that the coating was not in excellent condition in October 2006.

8.32 The epoxy coating system that has been applied to the OCNGS drywell exterior in the sand bed region is currently in excellent condition, and will be subject to appropriate periodic VT-1 inspections to ensure its continued integrity during the period of extended operation. The epoxy coating system can be expected to preclude further corrosion of the exterior shell in the sand bed region during the period of extended operation. The Board is unconvinced by the evidence presented by Citizens suggesting that the coating was not properly or completely applied, could rapidly fail due to high temperatures, or that it is currently in less than excellent condition.

IX. FUTURE CORROSION

9.1 This Section addresses the potential rate of corrosion in the sand bed region of the drywell shell that could theoretically occur during an extended twenty-year period of renewed plant operation. Again, this Section introduces the witnesses who provided the testimony on this topic, and then proceeds to the issue of potential future corrosion on the outside of the drywell shell. Finally, this Section addresses the potential for corrosion of the interior embedded surface of the drywell shell.

A. Witness Backgrounds

9.2 The information presented below regarding potential future corrosion of the drywell shell is based on the testimony of four witnesses for AmerGen, two witnesses for the NRC Staff, and one witness for Citizens.

9.3 AmerGen's witnesses on this topic were Mr. Barry Gordon, Mr. Peter Tamburro, Mr. Michael P. Gallagher, and Mr. Edwin Hosterman. The qualifications of Mr. Tamburro and Mr. Gallagher were previously described.

9.4 Mr. Gordon is corrosion and materials engineer with Structural Integrity Associates, Inc. ("SIA"), located in San José, California, has 38 years of experience in light-water reactors, is an instructor in corrosion engineering for the International Atomic Energy Agency ("IAEA") and the NRC, and is an Adjunct Professor at the Colorado School of Mines, in Golden, Colorado. AmerGen Dir., Part 6, A.1. Mr. Gordon is very familiar with the historical corrosion of the OCNGS drywell shell because he started working on the issue in the mid-1980s as the OCNGS drywell project manager for GE. AmerGen Dir., Part 6, A.3. During the course of that assignment, he had the opportunity to review, among other things, 2"-diameter core samples taken of the OCNGS drywell shell. *Id.* More recently, he prepared an evaluation report on the possible corrosion of steel embedded in concrete on the exterior of the drywell (June 5, 2006) and on effects of water on corrosion propensities of concrete embedded steel identified in the interior of the drywell (November 3, 2006). *Id.*

9.5 Mr. Edwin Hosterman is a Senior Staff Engineer in the Corporate Engineering Programs Group in Exelon's Headquarters in Kennett Square, Pennsylvania, with 30 years of experience as an engineer in the nuclear industry, with a primary focus on fluid flow and heat transfer analysis. AmerGen Dir., Part 6, A.1-2.

9.6 The NRC Staff's witnesses on this topic were Dr. James A. Davis, and Mr. Hansraj G. Ashar. Their background and qualifications are discussed above.

9.7 Citizens' witness was Dr. Hausler. His background and qualifications are discussed above.

B. Corrosion Mechanism

9.8 In Citizens' direct testimony, Dr. Hausler discussed the potential for future corrosion of the exterior drywell shell in the sand bed region and for corrosion of the interior embedded surface of the drywell shell. Dr. Hausler testified that the corrosion mechanism was "pitting" corrosion, and that this type of corrosion "increases exponentially with time." Citizens Dir., A. 21. Citizens rely on Dr. Hausler and an internal AmerGen e-mail from the 2006 refueling outage discussing observations of "pitting" by a plant engineer of the exposed interior drywell shell surface. *See* Citizens' Exh. 26.

9.9 AmerGen's expert, Mr. Gordon, testified that the corrosion mechanism—past or future—is "general corrosion", not pitting corrosion. AmerGen Rebut., Part 6, A.5. He bases his opinion on analyses performed by GE, while he was employed by GE, on core samples taken from multiple bays in the sand bed region in the 1980s, (*Id.* at A.7), and his knowledge of the sand bed region environment which allows protective films to form over carbon steel. *Id.* at A.6. Pitting corrosion requires the presence of a passive film which would not develop on carbon steel in the sand bed region. *Id.* Mr. Gordon also testified that corrosion rates for the drywell shell will decrease, rather than increase with time. *Id.*; Tr. at 493 (Gordon). This is the case because corrosion films that are produced on carbon steel create a diffusion barrier for metal cations and/or dissolved oxygen transport that reduces the amount of subsequent corrosion of the shell. *See* AmerGen. Rebut., Part 6, A.6.

9.10 The NRC Staff's expert, Dr. Davis, agrees with AmerGen that "[p]itting is a completely different corrosion mechanism that is not relevant to the alleged corrosion in pin holes in [*sic*] coating." Staff Rebut., A. 37. The Staff also testified that "the corrosion rate will not increase, but decrease over time." *Id.*

9.11 The Board finds Dr. Davis' and Mr. Gordon's testimony to be persuasive that general corrosion, not pitting corrosion, is the corrosion mechanism applicable here because Mr. Gordon's testimony is supported by analysis of actual drywell shell cores, his personal involvement with the historical corrosion as an employee with GE, and because the Board finds Dr. Davis and Mr. Gordon to be more credible experts than Dr. Hausler on this issue. Moreover, the photos of the exterior drywell shell surface in the sand bed region included in Applicant's Exhibit 40 demonstrate that the corrosion mechanism is general corrosion.

9.12 The Board does not find Dr. Hausler's testimony persuasive because his experience, and hence his arguments, appear to be based on oil field applications, where high temperatures, pressurized liquids, and highly aggressive environments containing hydrogen sulfide and organic acids, may be present. None of these conditions are present in the exterior or interior sand bed region. Nor does the Board find Citizens' Exhibit 26 to be persuasive on this subject as it is an anecdotal description by an AmerGen employee who was not identified on the record as having expertise in corrosion mechanisms.

9.13 However, the Board does not need to determine whether the mechanism is general or pitting corrosion. This is because, as discussed in Finding 9.29, below, any future corrosion remains speculative.

9.14 The Board also finds that whatever the corrosion mechanism is, the corrosion rate will decrease rather than increase with time based on the persuasive testimony of Dr. Davis and Mr. Gordon. Again, Dr. Hausler's opinion appears to be based on oil field applications, where high temperatures, pressurized liquids, and highly aggressive environments. None of these conditions are present in the exterior or interior sand bed region. There is no evidence to suggest that the corrosion mechanism in the future would be different than the corrosion mechanism of the past.

C. Future Corrosion Rate

9.15 In the case before us, corrosion requires the ongoing presence of an exposed metal surface and a cathodic reactant such as dissolved oxygen in an electrolyte (*e.g.*, water). AmerGen Dir., Part 6, A.5. The exterior epoxy coating system is designed to preclude corrosion because it separates the metal surface from the water containing the dissolved oxygen. *Id.* So for future corrosion to occur, the coating would have to fail to serve its function and water would need to be present.

9.16 Moisture in the air by itself is not sufficient to cause corrosion. AmerGen Dir., Part 6, A.7. Based on fundamental corrosion principles, moisture in the air would need to condense on the underlying metal shell to cause additional corrosion. *Id.* However, water condensing on an intact epoxy coating system would have no effect on the underlying metal. *Id.* And although Citizens may have taken a position to the contrary in their prefiled testimony, Dr. Hausler agreed at the hearing that exterior condensation—either during normal operations or outages—is not credible. Tr. at 412 (Hausler).

9.17 In their direct testimony, Citizens estimated a total potential future corrosion rate for both sides of the drywell shell of 0.041" per year. Citizens' Dir., A.16. Citizens based this annual rate on 0.039" of exterior corrosion and 0.002" of interior corrosion. The 0.039" corrosion rate was taken from Citizens' Exhibit 29, Mr. Barry Gordon's March 26, 2007 affidavit, which was filed by AmerGen in support of a Motion for Summary Disposition. To achieve this annual rate of corrosion, Dr. Hausler assumes that the exterior coating fails and water is present for the entire year. Citizens' Dir., A.17, A.21.

9.18 In their rebuttal testimony, Citizens increased the total potential future corrosion rate for both sides of the drywell shell to 0.050" per year: 0.039" for external corrosion and 0.010" to account for new water that might come into contact with the interior drywell shell's surface before that water's pH increased by its contact with the interior drywell concrete floor. Citizens' Rebuttal Statement, at 23; Citizens' Surr., A.40. No rationale was provided for the remaining 0.001".

9.19 Dr. Hausler also testified that the external sand bed region environment is "totally stagnant" (Citizens Exh. 39, at 19), or "has very limited air exchange" and, thus, "any moisture on the exterior of the shell would evaporate slowly." Citizens' Rebut., A.22; *see also* Tr. at. 65 (Hausler) ("we have mainly a stagnant area"). Dr. Hausler appears to believe that the only openings to the sand bed region are through the sand bed drains, which are connected to "tubes leading to polysterene bottles." *Id.* He believes that the three-inch space in the upper region between the exterior drywell shell and the concrete shield wall "is filled with insulation materials that would definitely . . . prevent any air flow through there." Tr. at 66 (Hausler). Dr. Hausler also testified that the ASHRAE calculation used by AmerGen for calculating of evaporation rates is applicable for pools and lakes and, therefore, is not applicable to the stagnant conditions at issue here. Citizens' Exh. 39, at 19; Tr. at 66 (evaporation will be "very much slower than what the pond equation . . . would have predicted").

9.20 Mr. Gordon testified that any future corrosion was speculative, AmerGen Dir., Part 6, A.11, and that no future corrosion can occur unless the epoxy coating system fails in some manner, and water comes into contact with the exposed metal surface of the carbon steel drywell shell. *Id.* at A.12, A.17. AmerGen believes the epoxy coating will prevent water from coming into contact with the underlying metal shell. *Id.* at A.7.

9.21 Mr. Gordon also testified that water in the sand bed region, if present, would be limited to a short period of time during refueling outages (*i.e.*, approximately 30 days every 24 months). AmerGen Dir., Part 6, A.13. Mr. O'Rourke testified at the hearing that the actual period during which the reactor cavity is filled with water during refueling outages is less than 30 days every other year. Tr. at 414 (O'Rourke); *see also* Tr. at 417 (Ray). Any resulting corrosion would necessarily be limited to this short period of time, since as Mr. Edwin Hosterman testified, the water in contact with the shell would evaporate in a few hours once the plant restarted. AmerGen Dir., Part 6, A.19. In his surrebuttal testimony, Mr. Hosterman explained that there is adequate air flow in the exterior sand bed region through "gaps between the drywell liner and the concrete shield wall" that create a "chimney" effect that facilitates evaporation. AmerGen Surr., Part 6, A.8. Therefore, the ASHRAE calculation was appropriate and conservative under the circumstances. *Id.* at A.11.

9.22 Finally, Mr. Gordon testified that he selected 0.039" as an annual corrosion rate because it was "unrealistic and overly conservative," because it reflected the worst rate measured in the external sand bed region *before* the sand was removed. AmerGen Rebut., Part 6, A.15,

9.23 Mr. Gordon further testified that 0.003" is a realistic annual rate of corrosion for the exterior (sand-less) sand bed region, *assuming*: (1) the coating was absent; (2) high-purity water was present all year long; (3) the temperature in the external sand bed region was 93° F;

and (4) the drywell shell had a "fresh," "shiny steel" surface. Tr. at 489-90, 493 (Gordon). Mr. Hosterman testified at the hearing that a temperature of 93° F is realistic for this area during outages. Tr. at 515 (Hosterman).

9.24 At the hearing, Dr. Hausler agreed that 0.003" is reasonable for an external sand bed region temperature of 93°F, although he correctly pointed out that the corrosion rate increases as the temperature increases. Tr. at 498 (Hausler). That testimony superseded his prior testimony in which he stated that "corrosion could be as rapid [in the future] as it was in the presence of sand." Citizens' Exh. 39, at 17.

9.25 Corrosion can be accelerated by the presence of impurities in the water, such as chloride, since ions present in the water increase conductivity of the electrolyte. Tr. at 491 (Gordon). It appears undisputed that water from the refueling cavity contains low levels of impurities and that the historical corrosion was accelerated by impurities present from other sources. Tr. at 490 (Gordon), 503 (Hausler). Mr. Gordon stated that the likely source of these impurities (*i.e.* chloride) was the sand itself. *Id* at 491 (Gordon). He testified that this sand was stored outside of the plant in the open marine (*i.e.,* salt) atmosphere during plant construction, prior to placement in the exterior sand bed region. *Id.* (Gordon).

9.26 It is undisputed that the chloride-containing sand is not present in the sand bed region today because the sand was removed during the 1992 refueling outage.

9.27 Dr. Hausler indirectly supported AmerGen's position that the sand was the source of the chlorides because he ruled out the Firebar-D (insulating material in the upper external drywell) as a source of corrosion-accelerating impurities, and he did not identify any other source. Tr. at 505 (Hausler).

9.28 The NRC Staff also appears to have concluded that future corrosion of the external drywell shell surface in the sand bed region is speculative because the epoxy coating in the sand bed region has been effective in reducing the potential for corrosion. Staff Dir., A.11. The NRC Staff did not provide any testimony concerning a proposed future corrosion rate or the rate of evaporation of any water that might enter the external sand bed region.

9.29 The Board finds it speculative and without adequate basis to conclude that any significant corrosion could occur on the exterior surface of the drywell shell in the sand bed region during the period of extended operation. For significant corrosion to occur from a buckling perspective, the epoxy coating would have to fail and water would need to come into contact with the drywell shell and remain undetected. As stated previously: (1) the Board has concluded that leakage from the reactor cavity is the only known source of water on the exterior of the drywell shell in the sand bed region and that AmerGen's commitments effectively eliminate the potential for such leakage during the only time when the reactor cavity is filled (Finding 7.25); and (2) the epoxy coating system has arrested and can be expected to preclude further corrosion of the exterior shell in the sand bed region during the period of extended operation (Findings 8.17, 8.32).

9.30 The 0.003" annual corrosion rate is bounding. This would be the case even if the Board were to find that the highest short term external corrosion rate discussed in any of the testimony, namely 0.039", was reasonable. Under that scenario, total corrosion would be limited to no more than 0.003" every *other* year, because the Board has found previously that it is reasonable to limit the presence of water in contact with the exterior drywell shell, should there by any water, to less than 30 days every other year (0.039"/52 weeks x 4 weeks (refueling outage) = 0.003" every other year).

9.31 Using the *bounding* scenario of 0.003" per year—which assumes no coating and the continual presence of water—would allow 0.060" of corrosion to occur during the 20-year period of extended operation. Even this is within the bounding available margin of 0.064" reported by AmerGen. However, as discussed above in Section VI, the Board finds that the bounding available margin is more than 0.200". Also, as discussed below, the Board does not believe this amount of corrosion (0.003" per year) should be supplemented by loss of metal through corrosion of the interior surface.

C. Corrosion of the Interior Embedded Surface of the Drywell Shell

9.32 The interior surface of the drywell shell that corresponds to the sand bed region is embedded in concrete from 8'11" to 11'0" (beneath the torus penetrations) and to 12'3" everywhere else. During the last refueling outage, this concrete floor up to about elevation 5 inches above the then bottom of Bay 5 trench was found to be essentially saturated with water. Applicant's Exh. 3, at 8-2.

9.33 Dr. Hausler testified that this water is causing up to 0.002" of corrosion per year on the interior surface. Citizens' Rebut., A.19. His opinion appears to be based on comparison of UT thickness measurements taken from the trenches in Bays 5 and 17 in 1986 and 2006, which suggests a loss of metal of about 0.038" during that 20-year interval. Staff Dir., A.11, citing Applicant's Exh. 12. Citizens also argue that up to 0.010" per year is reasonable if new water reaches the interior concrete floor because that water will be more corrosive as it will not have the same elevated pH. Citizens' Rebuttal Statement at 23; *see* Citizens' Rebut., A.18.

9.34 AmerGen's position is that the loss of around 0.038" is entirely attributable to corrosion of the exterior surface that occurred between 1986 and 1992, the end of which time the sand was removed and the exterior surface coated with epoxy. Applicant's Exhibit 3 at 8-4.

This was based on comparing the current thickness of 1.113" in the newly excavated portion of Bay 5 trench in 2006 with the design thickness of 1.154". *Id.* at 8-3, 8-4.[116] This portion of the shell had been embedded in concrete since construction of OCNGS and was found to be in contact with water. *Id.* at 8-2, 8-3. There was no measurable corrosion on the surface of this newly-exposed shell. *Id.* At the hearing, Mr. Gordon stated that the internal corrosion rate is "essentially negligible." Tr. at 497 (Gordon).

9.35 Mr. Gordon also testified that any water that would be in contact with the interior surface of the embedded drywell shell would have a high pH caused by its contact with the concrete and/or concrete pore water. Tr. at 497 (Gordon); AmerGen Surr., Part 6, A.4. This high pH is caused by the abundant amounts of calcium hydroxide, and relatively small amounts of compounds of alkali elements sodium and potassium, in the concrete. AmerGen Rebut., Part 6, A.10; Applicant's Exh. 60, at 57.

9.36 For proof, AmerGen points to the analytical results taken during the 2006 refueling outage of the water that is in contact with the interior surface of the drywell shell. This water was measured to have a pH of approximately 8.4 to 10.2 and low levels of chloride and sulfate, which is consistent with NRC Generic Aging Lessons Learned (GALL) Report (Vol. 2, Rev. 1, at II A.1 through 5) and EPRI embedded steel guidelines for an environment that poses no aging management concerns. AmerGen Rebutt., Part 6, A.10. These water samples also had high levels of calcium which indicate slow migration through the concrete. *Id.* Any subsequent water ingress into the concrete floor will also become high pH concrete pore water before it can come into contact with the interior drywell shell, which will also mitigate corrosion. *Id.*

116 For perspective, between 1986 and 1992, the wall thickness loss at the thinnest location was reported to be 0.070", resulting in a linear corrosion rate during this time period of about 0.012" per year. Staff's Exh. 1, at 4-43 (cited in Staff Dir., A.22).

9.37 Finally, the air inside the drywell shell is inerted with nitrogen during operations, severely reducing the oxygen available to allow corrosion. AmerGen Rebut., Part 6, A.10. In other words, the interior of the drywell is air tight during operations. *Id.* at A.11. Ambient air is present in the drywell during outages, but is replaced with nitrogen for operations. *Id.* While AmerGen is permitted to operate OCNGS with up to 4% oxygen inside the drywell, it is typically operated with an oxygen concentration of less than 2%. *Id.* Thus, there would be an order of magnitude less oxygen available to support corrosion. *Id.* at A.12. However, oxygen is not the limiting factor for potential corrosion of the interior embedded drywell shell surface where the presence of the concrete itself provides a protective pH of any water that would be adjacent to the drywell shell. *Id.* Thus, the amount of oxygen has less importance here than it would for carbon steel not embedded in concrete. *Id.*

9.38 The NRC Staff agrees with AmerGen that "[i]t is reasonable to assume that most of the exterior corrosion took place between 1986 and 2006, when the exterior surface of the drywell in the sand bed region had wet sand present and was not protected by the three-layer epoxy coating." Staff Surr., A.45. The Staff also concurred that the interior surface of the drywell shell "was determined to not be a corrosive environment because the water had reacted with the concrete and had become a non-corrosive (*i.e.*, basic) environment." Staff Dir., A.17. Finally, the NRC Staff agrees that "[b]ecause the drywell is inerted during operation, the likelihood of [sic] corrosive environment existing inside the drywell during operation of the plant is very low." Staff Dir., A.12(a).

9.39 No measurable corrosion is expected to occur on the internal surface of the drywell shell in the sand bed region. The Board does not find Citizens' annual corrosion rate of

0.002" convincing, as it ignores (*i.e.*, gives no credit for) the known exterior corrosion between 1986 and 1992 in at least Bay 17.

9.40 The Board also does not find Citizens' annual corrosion rate of 0.010" convincing for four reasons. First, it is based on multiplying the 0.002" annual corrosion rate by five and, as just stated, the Board does not find the 0.002" a reasonable ongoing corrosion rate. Second, multiplying 0.002" by five is unsupported in the record as a standard in the industry. AmerGen Surr., Part 6, A.5 ("normal corrosion engineering practice is to conservatively double the general corrosion rate to provide extra margin"). Third, an annual corrosion rate of 0.010" ignores the fact that new water reaching the floor of the interior drywell will immediately come into contact with concrete because the floor is made of concrete. This water will, therefore, become elevated in pH and become essentially non-corrosive as it must necessarily migrate *through* the concrete before it comes into contact with the drywell shell's surface. This is the case because AmerGen has now caulked the interface between the drywell shell and the concrete curb. Tr. at 420 (O'Rourke). And finally, Citizens applied the rate of 0.010" over an entire year, when it is clear from Mr. Gordon's testimony that it would not take a year for any new water to become essentially non-corrosive.

9.41 In conclusion, the Board finds that no significant corrosion is expected to occur in the sand bed region at a rate that would warrant UT measurements at an interval shorter than every other refueling outage (*i.e.*, every four years).

X. CONCLUSIONS OF LAW

Based upon a review of the entire hearing record and the foregoing discussion and Findings of Fact, the Board concludes as follows:

10.1 AmerGen's scheduled UT frequency is adequate to ensure the actual thickness of the sand bed region of the OCNGS drywell shell remains above the applicable acceptance criteria throughout the period of extended operation. Thus, AmerGen has demonstrated that the effects of aging will be adequately managed so that the drywell shell in the sand bed region will be maintained consistent with the CLB for the period of extended operation, as required by 10 C.F.R. § 54.21.

10.2 There is reasonable assurance that the OCNGS current licensing basis will be maintained throughout the period of extended operation, as required by 10 C.F.R. § 54.29.

10.3 As described in Finding 4.20 above, the Board imposes one additional condition of the renewed license: AmerGen must commit to periodic inspections of the sand bed drains to verify that they are not blocked, consistent with its existing internal procedures.

XI. ORDER

WHEREFORE, IT IS ORDERED, in accordance with the Atomic Energy Act of 1954, as amended, and the rules and regulations of the Commission, that the Director of Nuclear Reactor Regulation is authorized to issue to AmerGen Energy Company, LLC, a renewed operating license for the Oyster Creek Nuclear Generation Station, for a period of twenty years, consistent with the terms of this Initial Decision, and the Staff's review of the License Renewal Application.

IT IS FURTHER ORDERED, in accordance with 10 C.F.R. § 2.341(b)(1), that any party to this proceeding may file a petition for review of this Initial Decision with the Commission within fifteen (15) days after service of this initial decision.

IT IS FURTHER ORDERED, in accordance with 10 C.F.R. § 2.340(g) and § 2.1210, that this Initial Decision shall constitute the final decision of the Commission forty (40) days after its issuance, unless there is a petition for Commission review filed, or the Commission decides to review this Initial Decision under 10 C.F.R. §2.1210(a)(2) or (3).

Respectfully submitted,

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AMERGEN ENERGY COMPANY, LLC

Dated in Washington, D.C.
this 10th day of October 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	)	October 10, 2007
AmerGen Energy Company, LLC	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "AmerGen's Proposed Findings of Fact and Conclusions of Law" were served this day upon the persons listed below, by e-mail and first class mail, unless otherwise noted.

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