UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
ENTERGY NUCLEAR VERMONT YANKEE, LLC	)	Docket Nos. 50-271-LR
AND ENTERGY NUCLEAR OPERATIONS, INC.	)	
	)	ASLBP No. 06-849-03-LR
(Vermont Yankee Nuclear Power Station)	)	

NRC STAFF'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW, AND ORDER IN THE FORM OF AN INITIAL DECISION

Lloyd B. Subin
Mary C. Baty
Jessica A. Bielecki
Counsel for NRC Staff

August 25, 2008

TABLE OF CONTENTS

August 25, 2008

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
ENTERGY NUCLEAR VERMONT YANKEE, LLC	)	Docket No. 50-271-LR
AND ENTERGY NUCLEAR OPERATIONS, INC.	)	
	)	ASLBP No. 06-849-03-LR
(Vermont Yankee Nuclear Power Station)	)	

NRC STAFF'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW, AND ORDER IN THE FORM OF AN INITIAL DECISION

I. INTRODUCTION

1. This initial decision rules on all outstanding issues in this 10 C.F.R. Part 2, Subpart L proceeding concerning contentions challenging the Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. ("Entergy" or "licensee" or "Applicant") application for renewal of the operating license for the Vermont Yankee Nuclear Power Station ("VYNPS" or "Vermont Yankee" or "VY"), in Windham County, Vermont. The proposed renewal would authorize the facility to operate 20 years beyond its current expiration date of March 21, 2012. New England Coalition, Inc. ("NEC") sponsored three contentions challenging the adequacy of Entergy's 1) program for managing the effects of metal fatigue; 2) plan to monitor and manage the aging of the steam dryer; and 3) plan to monitor and manage the aging of plant piping due to flow-accelerated corrosion.

2. After considering all of the evidence in this proceeding, we find the record shows that, contrary to NEC's contentions, Entergy has met its burden of demonstrating that its plans for managing metal fatigue, the aging of the steam dryer, and the aging of plant piping due to flow-accelerated corrosion are adequate to manage the effects of aging so that the intended

functions of the components subject to metal fatigue, the steam dryer, and piping subject to flow-accelerated corrosion, will be maintained consistent with the current licensing basis for the period of extended operation.

II. BACKGROUND

A. Procedural History

3. By letter dated January 25, 2006, Entergy submitted to the U.S. Nuclear Regulatory Commission ("NRC" or "Commission") an application for renewal,[1] pursuant to 10 C.F.R. Part 54, of Operating License No. DPR-28 for the Vermont Yankee Nuclear Power Station. The current license expires March 21, 2012.

4. The NRC published a notice of receipt of the license renewal application ("LRA") on February 6, 2006 (71 Fed. Reg. 6102). The Staff published a notice of acceptance for docketing of the application and notice of opportunity for hearing on March 27, 2006 (71 Fed. Reg. 15,220). In response to the notice of docketing and opportunity for hearing, NEC filed a petition for leave to intervene on May 26, 2006. Petitions to intervene were also filed by the Vermont Department of Public Service ("DPS"), the Massachusetts Attorney General ("AG"), and the Town of Marlboro, Vermont ("Marlboro").

5. In *Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), LBP-06-20, 64 NRC 131 (2006), the Board rejected

---

[1] Vermont Yankee Nuclear Power Station License Renewal Application (Jan. 25, 2006) (ADAMS Accession No. ML060300085). Entergy has since supplemented and amended its application several times.

the AG's[2] and Marlboro's contentions[3] but admitted four of NEC's contentions[4] and one of DPS's.[5] On appeal, the Commission reversed the Board's decision to admit NEC Contention 1. *See Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), CLI-07-16, 65 NRC 371 (2007). The Board approved a settlement of the admitted DPS contention. *See* Order (Approving Settlement of DPS Contention 1) (May 31, 2007) (unpublished).

6. The Staff issued "Safety Evaluation Report Related to the License Renewal of Vermont Yankee Nuclear Power Station" on February 25, 2008, and published it as NUREG-1907 "Safety Evaluation Report: Related to the License Renewal of Vermont Yankee Nuclear Power Station" in May 2008 (ADAMS Accession Nos. ML081430057 (Vol. 1) and

---

[2] *Vermont Yankee Nuclear Power Station,* LBP-06-20, 64 NRC at 152-162.

[3] *Id.* at 201.

[4] The admitted contentions were:

- DPS Contention 1: Entergy's License Renewal Application does not contain adequate information regarding aging management of primary containment concrete.
- NEC Contention 1: Entergy failed to assess impacts to water quality.
- NEC Contention 2: Entergy's License Renewal Application does not include an adequate plan to monitor and manage the effects of aging [due to metal fatigue] on key reactor components that are subject to an aging management review, pursuant to 10 C.F.R. § 54.21(a) and an evaluation of time limited aging analysis under 10 C.F.R. § 54.21(c).
- NEC Contention 3: Entergy's License Renewal Application does not include an adequate plan to monitor and manage aging of the steam dryer during the period of extended operation.
- NEC Contention 4: Entergy's License Renewal Application does not include an adequate plan to monitor and mange aging of plant piping due to flow-accelerated corrosion during the period of extended operation.

See generally LBP-06-20, 64 NRC 131.

[5] Also in LBP-06-20, the Board granted NEC's and DPS's notices of adoption of each other's contentions to the extent that NEC's and DPS's contentions were admitted. *Id.* at 208.

ML081430109 (Vol. 2)).

1. Procedural History of NEC Contention 2

7. On July 12 and September 4, 2007, NEC filed motions to file a timely new or amended contention regarding Entergy's program to manage the aging effects of metal fatigue, claiming that Entergy's reanalysis was flawed and thus failed to meet the requirements of 10 C.F.R. § 54.21.[6] In LBP-07-15, the Board admitted NEC's new contention (identifying it as NEC 2A) alleging: the "analytical techniques employed in Entergy's [environmentally corrected CUF] or CUFen Reanalysis were flawed by numerous uncertainties, unjustified assumptions, and insufficient conservatism, and produced unrealistically optimistic results. Entergy has not, by this flawed reanalysis, demonstrated that the reactor components assessed will not fail due to metal fatigue during the period of extended operation." *Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), LBP-07-15, 66 NRC 261, 270 (2007).

8. On March 17, 2008, NEC filed a Motion to File a Timely New of Amended Contention, seeking leave to file a new or amended contention on metal fatigue addressing Entergy's confirmatory analysis. On April 24, 2008, the Board issued an "Order (Granting Motion to Amend NEC Contention 2A)" (unpublished) ("April 24 Order"). In the Order, the Board deemed NEC's April 17 Amendment to be "a subset of Contention 2A" designed to prevent NEC from being foreclosed from challenging Entergy's CUF confirmatory analysis. April 24 Order at 2. Because the deadline for NEC to file its initial statements of position was approaching, the

---

[6] *See* New England Coalition, Inc's (NEC) Motion to File a Timely New or Amended Contention (July 12, 2007); New England Coalition, Inc's (NEC) Motion to File a Timely New or Amended Contention (Sept. 4, 2007).

Board did not endeavor to restate Contention 2A or NEC's March 17 Amendment, instead, the Board designated NEC's March 17 Amendment Contention 2B. *Id.*

2. Procedural History of NEC Contention 3 (Steam Dryer)

9. On April 19, 2007, Entergy filed a motion for summary disposition of NEC Contention 3 (Steam Dryer). *See* Entergy's Motion for Summary Disposition of New England Coalition's Contention 3 (Steam Dryer) (Apr. 19, 2007). The Staff supported Entergy's motion. *See* NRC Staff Answer in Support of Entergy's Motion for Summary Disposition of New England Coalition Contention 3 (Steam Dryer) (May 9, 2007). NEC opposed Entergy's motion and also requested that the Board wait until the inspection results from the May 2007 refueling outage were released before ruling on Entergy's motion for summary disposition. *See* New England Coalition, Inc.'s (NEC) Opposition to Entergy's Motion for Summary Disposition of NEC's Contention 3 (Steam Dryer) (May 9, 2007). The Board issued an Order granting NEC's request to defer a decision on Entergy's motion for summary disposition until after the results of the May 2007 Steam Dryer inspection were available. Order (Granting Motion to Defer and Setting Schedule) (July 13, 2007) (unpublished). Therein, the Board also stated that NEC was permitted to file a supplemental response to Entergy's motion for summary disposition after the inspection results were released and that the Staff and Entergy could respond to any supplement filed by NEC. *Id.*

10. After the 2007 steam dryer inspection results were released, NEC filed a supplement to its Opposition to Entergy's Motion for Summary Disposition. *See* New England Coalition, Inc.'s (NEC) Supplement to Opposition to Entergy's Motion for Summary Disposition of New England Coalition Contention 3 (Steam Dryer) (July 19, 2007). Entergy and the Staff responded to NEC's supplement. *See* Entergy's Response to New England Coalition's Supplement to Opposition to Entergy's Motion for Summary Disposition of New England

Coalition Contention 3 (Steam Dryer) (July 26, 2007); NRC Staff Answer to NEC's Supplement to Opposition to Entergy's Motion for Summary Disposition of NEC Contention 3 (Steam Dryer) (July 26, 2007).

11. In "Memorandum and Order (Ruling on Motion for Summary Disposition of NEC Contention 3)" (Sept. 11, 2007) (unpublished) ("NEC 3 SD Order") the Board granted in part and denied in part Entergy's motion. The Board granted Entergy's motion:

> (1) as it relates to the specific use and benchmarking of the CFD and ACM computer models in monitoring potential steam dryer cracking, and (2) as it relates to NEC's inference that the steam dryer is not continuously monitored as part of the aging management program for the license renewal period.

NEC 3 SD Order at 3. The Board denied Entergy's motion as it related to NEC's assertion "that the status of the steam dryer must be continuously monitored and assessed by a competent engineer" because Entergy did not provide information regarding the qualifications of the personnel performing the monitoring. *Id.* at 11. The Board also denied Entergy's motion as it related to asserted inadequacies in "Entergy's assessment of the monitoring data collected from the aging management program for the steam dryer" and failure to include some form of stress load analysis in its program. *Id.* at 13-14.

3. Procedural History of NEC Contention 4 (Flow-Accelerated Corrosion)

12. On June 5, 2007, Entergy filed a motion for summary disposition of NEC Contention 4. *See* Entergy's Motion for Summary Disposition of New England Coalition's Contention 4 (Flow Accelerated Corrosion). The Staff supported Entergy's motion. *See* NRC Staff Answer in Support of Entergy's Motion for Summary Disposition of NEC Contention 4 (Flow-Accelerated Corrosion) (June 25, 2007). NEC opposed the motion. *See* New England Coalition, Inc.'s (NEC) Opposition to Entergy's Motion for Summary Disposition of NEC's Contention 4 (Flow-Accelerated Corrosion) (July 16, 2007).

13. In "Memorandum and Order (Ruling on Motion for Summary Disposition of NEC 4)" (Aug. 10, 2007) (unpublished) at 2, the Board denied Entergy's motion for summary disposition concluding that the pleadings revealed a "classic battle of the experts," precluding summary disposition.

B. Prehearing Submissions and Orders

14. On April 28, 2008, NEC filed its initial statement of position.[7] On May 13, 2008, Entergy and the Staff filed initial statements of position.[8] On June 2, 2008, the parties filed rebuttal presentations and testimony.[9] In addition, the parties filed motions in limine regarding prefiled testimony and exhibits.[10] The parties also filed responses to these motions in limine.[11]

---

[7] *See* New England Coalition, Inc. Initial Statement of Position (Apr. 28, 2008).

[8] *See* Entergy's Initial Statement of Position on New England Coalition's Contentions (May 13, 2008); NRC Staff Initial Statement of Position on NEC Contentions 2A, 2B, 3, and 4 (May 13, 2008).

[9] *See* Entergy's Supplemental Statement of Position on New England Coalition Contentions 2A/2B (June 2, 2008); New England Coalition, Inc. Rebuttal Statement of Position (June 2, 2008); and NRC Staff Rebuttal Testimony Concerning NEC Contention 4 (June 2, 2008). On June 6, 2008 NEC filed "New England Coalition, Inc's Motion to Late-File Testimony of Ulrich Witte." On June 23, 2008, Entergy Filed "Entergy's Response in Opposition to NEC Motion to File Untimely Rebuttal Testimony of Ulrich Witte."

[10] The parties filed the following motions in limine on initial and rebuttal testimony: Entergy's Motion in Limine (June 12, 2007); New England Coalition, Inc.'s Motion to Strike NRC Staff Rebuttal Testimony Concerning NEC Contention 4 (June 12, 2007); NRC Staff's Motion in Limine to Strike Testimony and Exhibits Filed by New England Coalition, Inc. (June 12, 2008).

[11] The parties filed the following responses to motions in limine: NRC Staff's Response to NEC's Motion to Strike NRC Staff's Rebuttal Testimony Concerning NEC Contention 4 (June 19, 2008); NRC Staff's Answer in Support of Entergy's Motion in Limine (June 19, 2008); Entergy's Response in Support of Staff's Motion in Limine (June 19, 2008); New England Coalition, Inc's Opposition to Entergy's Motion in Limine (June 19, 2008); New England Coalition, Inc's Opposition to NRC Staff's Motion in Limine to Strike Testimony and Exhibits Filed by New England Coalition, Inc. (June 20, 2008). Entergy also filed "Entergy's Response in Opposition to NEC's Motion to Strike Staff's Rebuttal Testimony" (June 23, 2008).

In accordance with Order (Granting [Entergy's] Motion to Extend Time to File Motions in Limine with Regard to Ulrich Witte's Testimony and Setting Deadline for Answers Thereto) (June 11, 2008), (continued. . .)

On June 27, 2008, NEC filed "Motion to File Corrections to Exhibits and to Withdraw Certain Testimony of Ulrich Witte."

15. On June 27, 2008, the Board issued: Order (Regarding Briefing on Certain Legal Issues). Therein, the Board requested that the parties brief issues related to performance of TLAAs and referencing Staff guidance to demonstrate that aging will be adequately managed. The parties filed initial briefs on July 9, 2008[12] and reply briefs on July 15, 2008.[13]

16. On July 8, 2008, the parties filed "Joint Stipulations," in which they agreed to certain facts pertaining to Contentions 2A, 2B, 3, and 4. Those stipulations are binding on the parties and are incorporated into these findings.

17. On July 16, 2008, the Board ruled on the parties' motions in limine. *See* Order (Rulings on Motions to Strike and Motions in Limine) ("Limine Order"). The Board granted Entergy's motion to strike portions of NEC's rebuttal statement of position, the associated testimony of Dr. Joram Hopenfeld (second paragraph of A19), and NEC Exhibit NEC-JH_67 that

---

(. . .continued)

Entergy and the Staff filed motions in limine concerning Ulrich Witte's late-filed rebuttal testimony on June 23, 2008. *See* Entergy's Motion in Limine to Exclude Rebuttal Testimony of Ulrich Witte; NRC Staff Motion in Limine to Strike Late-Filed Rebuttal Testimony of Ulrich Witte. Also in accordance with the Board's Order, NEC filed "New England Coalition, Inc.'s Opposition to Entergy's and the NRC Staff's Motions in Limine to Exclude Rebuttal Testimony of Ulrich Witte" (June 30, 2008).

[12] *See* Entergy's Answers to Licensing Board Questions (July 9, 2008); New England Coalition, Inc. Supplemental Prehearing Brief (July 9, 2008); Vermont Department of Public Service Brief in Response to June 27, 2008 Order (July 9, 2008); NRC Staff's Brief in Response to Board Order (July 9, 2008).

[13] *See* Entergy's Reply Response to Licensing Board Questions (July 15, 2008); New England Coalition, Inc. Supplemental Prehearing Reply Brief (July 15, 2008); Vermont Department of Public Service Response to Entergy and NRC Staff Brief on Pre-Trial Legal Issues (July 15, 2008); NRC Staff's Reply Brief (July 15, 2008).

referred to the metal fatigue issue in the Indian Point license renewal proceeding. Limine Order at 2.

18. The Board granted in part and denied in part the request to strike Ulrich Witte's initial testimony (Exh. NEC-UW_03) for lack of expertise. *Id.* at 7. The Board found that Mr. Witte was qualified under Rule 702 of the Federal Rules of Evidence to testify on "configuration management issues" but not qualified to testify on "the predictive accuracy of the CHECWORKS model, the requirements necessary to benchmark it, and other technical aspects of predicting and modeling FAC. *Id.* at 8. Accordingly, the Board struck portions of Exhs. NEC-UW_01 and NEC-UW_03. *See id.* at Attachments 1 & 2.

19. The Board granted Entergy's and the Staff's motions to strike Mr. Witte's testimony on the subject matter of NEC Contentions 2A and 2B, finding that there was no evidence that Mr. Witte was qualified to testify on the subject of Contentions 2A and 2B. Thus, the Board struck those portions of Mr. Witte's rebuttal testimony. *See id.* at Attachment 4.

20. The Board also granted the Staff's motion to strike portions of Dr. Hopenfeld's pre-filed testimony (Exhs. NEC-JH_01 at A8; NEC-JH_63 at A19) in which Dr. Hopenfeld asserted that Entergy intentionally failed to disclose information in order to thwart public scrutiny.[14] Limine Order at 12.

21. Finally, the Board denied NEC's motion to strike the Staff's rebuttal testimony. *Id.* at 13.

22. The Board held two limited appearance sessions on October 11, 2007 in

---

[14] Although NEC failed to comply with this order by striking this testimony prior to submitting it at the hearing, the Board did not consider it.

Brattleboro, Vermont.[15]

23. An evidentiary hearing concerning the admitted contentions was held at the Windham County Courthouse in Newfane, Vermont during the period of July 21-24, 2008. At the commencement of the hearing, the Staff made an oral motion to withdraw the pre-filed testimony contained in the "Affidavit of Kenneth C. Chang Concerning NEC Contentions 2A & 2B (Metal Fatigue)" because Dr. Chang was not available to testify at hearing. Tr. 721-722. In response, NEC asked that if the Staff's motion were granted, its expert should be able to refer to Dr. Chang's testimony but portions of the Staff's SER authored by Dr. Chang should be stricken along with the exhibits to Dr. Chang's testimony. Tr. 722-23, 727-728. NEC further asked for an opportunity to move to strike any portion of the pre-filed testimony contained in the "Affidavit of John R. Fair Concerning NEC Contentions 2A & 2B (Metal Fatigue)" that referenced or repeated information included in Dr. Chang's testimony. Tr. 767-69. After taking the matter under advisement, the Board ruled that Dr. Chang's testimony would be admitted as an exhibit along with the exhibits referenced therein. Tr. 1176, 1465-66.

24. During the hearing, the Board received into the evidentiary record pre-filed written direct and rebuttal testimony on each of the admitted contentions.[16] It admitted 93 Applicant Exhibits: E2-02 through E2-37, E3-02 through E3-16, and E4-02 to E4-43; 94 NEC Exhibits: NEC-JH_02 through 66, NEC-JH_68-72; NEC-RH_02, 03, and 05; NEC-UW_02-22,

---

[15] *See* Notice (Notice of Opportunity to Make Oral or Written Limited Appearance Statements Concerning Proposed License Renewal) 72 Fed. Reg. 40,341 (July 24, 2007).

[16] Testimony on Contentions 2A & 2B admitted at Tr. 763 (Entergy), 768 (Staff), 779 (NEC). Testimony for Contention 3 admitted at Tr. 1186-87 (Entergy), 1190 (Staff), 1191 (NEC stated Dr. Hopenfeld's Contention 3 testimony had been admitted with his Contentions 2A & 2B testimony); Testimony on Contention 4 admitted at Tr. 1427 (Entergy), 1432 (Staff), 1437 (NEC).

and 23; and 23 Staff Exhibits: 1, 2, 6-23, and A-D. The record for this proceeding was closed on July 24, 2008, subject only to transcript corrections. Tr. 1735-36. On August 13, 2008, the parties submitted: "Joint Proposed Transcript Corrections."

III. GENERAL LEGAL AND REGULATORY REQUIREMENTS[17]

A. Scope of this Proceeding

25. The scope of license renewal proceedings is limited. The Commission's "[l]icense renewal reviews are not intended to 'duplicate the Commission's ongoing review of operating reactors.'" *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 & 4), CLI-01-17, 54 NRC 3, 7 (2001) (citing Final Rule, "Nuclear Power Plant License Renewal," 56 Fed. Reg. 64,943, 64,946 (Dec. 13, 1991)). The license renewal safety review process focuses on the "potential detrimental effects of aging that are not routinely addressed by ongoing regulatory oversight programs." *Id*. Consequently, 10 C.F.R. Part 54 "requires renewal applicants to demonstrate how their programs will be effective in managing the effects of aging during the period of extended operation." *Id.* at 8 (citing 10 C.F.R. § 54.21(a)).

26. Applicants are required to "identify any additional actions, i.e., maintenance, replacement of parts, etc., that will need to be taken to manage adequately the detrimental effects of aging." *Id.* (citing Final Rule, Nuclear Power Plant License Renewal: Revisions, 60 Fed. Reg. 22,461, 22,479 (May 8, 1995)). The Commission has recognized that these "[a]dverse aging effects generally are gradual and thus can be detected by programs that ensure sufficient inspections and testing." *Id.* (citing 60 Fed. Reg. at 22,475). Therefore,

---

[17] This section addresses legal and regulatory requirements applicable to all of NEC's Contentions.

license renewal proceedings are limited to a "review of the plant structures and components that will require an aging management review for the period of extended operation and the plant's systems, structures, and components that are subject to an evaluation of time-limited aging analyses." *Duke Energy Corp.* (McGuire Nuclear Station, Units 1 and 2; Catawba Nuclear Station, Units 1 and 2), CLI-01-20, 54 NRC 211, 212 (2001) (citing 10 C.F.R. §§ 54.21(a) and (c), 54.4; 60 Fed. Reg. 22,461).

27. In addition to the limited scope of license renewal proceedings in general, this proceeding is also limited by the admitted contentions. The "'contention's proponent, not the licensing board,' . . . 'is responsible for formulating the contention and providing the necessary information to satisfy the basis requirement for the admission of contentions.'" *USEC Inc.* (American Centrifuge Plant) CLI-06-10, 63 NRC 451, 457 (citing Statement of Policy on Conduct of Adjudicatory Proceedings, CLI-98-12, 48 NRC 18, 22 (1998)). Thus, testimony and exhibits that raise issues outside the scope of the admitted contentions are irrelevant because the scope of license renewal proceedings is limited to the issues raised by the admitted contentions[18] and the scope of the admitted contentions are limited by their bases. *See Public Service Co. of New Hampshire* (Seabrook Station, Units 1 & 2), ALAB-899, 28 NRC 93, 97 (1988) (stating that contentions and bases must be stated with specificity to put the parties on notice of the issues that they must defend against or oppose and that the scope of a contention is defined by the contention and its stated bases).

28. The Commission's regulations state that the Board must make "findings of fact

---

[18] Statement of Policy on Conduct of Adjudicatory Proceedings, (CLI-98-12) 48 NRC 18, 22-23 (1998).

and conclusions of law on matters *put into controversy by the parties* to the proceeding . . . ." 10 C.F.R. § 2.340(a) (emphasis added). A Board may only consider matters *sua sponte* where it finds that a serious safety, environmental, or common defense and security matter exists and the Commission, upon referral by the Board, approved an examination of and decision on the matter. *See id.* Thus, a Board cannot consider an issue *sua sponte* absent the Commission's approval upon referral. *Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc*. (Vermont Yankee Nuclear Power Station), LBP-06-18, 63 NRC 830, 840 n.21 (2006) ("In 2004 the Commission amended the regulations allowing a Board to examine an issue *sua sponte* 'only where . . . the Commission approves such examination and decision upon referral of the question' to the Commission . . . [t]he pre-2004 regulations had no such requirement.") (internal citations omitted)).

29. Furthermore, this Board is precluded from considering matters not in the evidentiary record. *See Pacific Gas & Electric Co*. (Diablo Canyon Nuclear Power Plant, Units 1 & 2), ALAB-580, 11 NRC 227, 230 (1980) (stating that "it is a statutory requirement that the adjudicatory decisions of this Commission stand or fall on the basis of the record on which they rest").

B. License Renewal Requirements

30. Sections 54.21 and 54.29 of 10 C.F.R. Part 54 set forth the standards governing renewal of a plant's operating license. Pursuant to § 54.21, Entergy must demonstrate that: its fatigue monitoring program is adequate to manage the effects of metal fatigue during the period of extended operation (NEC Contentions 2A and 2B); its steam dryer aging management plan is adequate to manage the aging effects so that the intended function of the steam dryer will be maintained during the period of extended operation consistent with the current licensing basis (NEC Contention 3); and its plan to manage the aging effects of flow-accelerated corrosion is

adequate to ensure that the intended functions of susceptible piping will be maintained consistent with the current licensing basis ("CLB") during the period of extended operation (NEC Contention 4).

31. Pursuant to § 54.29, in order to renew Vermont Yankee's license, the Staff must find that there is reasonable assurance[19] that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB. Together, §§ 54.21 and 54.29 require that Entergy establish an aging management program that is adequate to provide reasonable assurance that the intended functions of Vermont Yankee's steam dryer and piping subject to metal fatigue or flow-accelerated corrosion will be maintained in accordance with the CLB during the period of extended operation. Pursuant to § 54.33(d), the licensing basis for the renewed license includes the CLB defined in § 54.3(a). Thus, the CLB during the initial term continues into any renewal term. 56 Fed. Reg. at 64,953.

32. The Commission's regulations do, however, permit changes to the CLB so long as "[r]elevant information concerning changes to the CLB and plant modifications required to

---

[19] Although reasonable assurance appears in many areas of Commission case law and regulations, it is not specifically defined in either the Atomic Energy Act or the Commission's regulations. Reasonable assurance of adequate protection is based upon technical judgment, not application of a mechanical verbal formula, a set of objective standards, or specific confidence interval. *See Union of Concern Scientists v. NRC,* 880 F.2d 552, 558 (D.C. Cir. 1989) (stating that "adequate protection" may be given content through case-by-case applications of technical judgment and that Congress neither defined nor commanded the Commission to define adequate protection). *See also* Revision of Backfitting Process for Power Reactors, 53 Fed. Reg. 20,603, 20,605 (June 6, 1988) (stating that like "adequate protection," "reasonable assurance" is a determination based upon full consideration of all relevant information).

The Commission has explicitly stated that reasonable assurance does not denote a specific statistical parameter. *See* Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada, 66 Fed. Reg. 55,732, 55,739-40 (Nov. 2, 2001). The touchstone of reasonable assurance of adequate protection of public health and safety is compliance with the Commission's regulations. *See Maine Yankee Atomic Power Co. (*Maine Yankee Atomic Power Station), ALAB-161, 6 AEC 1003, 1009 (1973).

demonstrate that aging effects for systems, structures, and components requiring an aging management review for license renewal [are] described in the application for license renewal." 60 Fed. Reg. at 22,482 (citing 10 C.F.R. § 54.21(a)(3) and (c)).

33. The Commission has accepted the use of "commitments to monitor, manage, and correct age-related degradation unique to license renewal" to satisfy the requirements of § 54.21. 56 Fed. Reg. at 64,946. The Commission reaffirmed its position to accept commitments in the 1995 revisions to the License Renewal Rule. *See* 60 Fed. Reg. at 22,473.

34. The Commission has "rejected the notion that all commitments made by the Licensee must be memorialized as express license conditions in order to be enforceable." *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), LBP-05-21, 62 NRC 248, 311 (2003) (citing *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-01-9, 53 NRC 232, 235 (2001)).[20] Thus, commitments that are made part of a facility's CLB by incorporation in the facility's final safety analysis report ("FSAR") are enforceable even if they do not take the form of a formal license condition. *See Private Fuel Storage LLC* (Independent Spent Fuel Storage Installation), CLI-03-8, 58 NRC 11, 21 (2003).[21]

---

[20] Applicants are bound by record keeping requirements to keep all information regarding commitments that document compliance with Part 54, in an auditable and retrievable form. *See* 10 C.F.R. § 54.37(a) ("The licensee shall retain in an auditable and retrievable form for the term of the renewed operating license or renewed combined license all information and documentation required by, or otherwise necessary to document compliance with, the provisions of this part.").

[21] The commitments Entergy has made in its license renewal application will be part of Vermont Yankee's CLB when they are incorporated into Vermont Yankee's next FSAR update in accordance with 10 C.F.R. §§ 50.71(e) and 54.21(d). These commitments will, therefore, be enforceable by the Commission and "any person" pursuant to 10 C.F.R. § 2.206. *See* 10 C.F.R. § 54.3 (defining current licensing basis as including licensee commitments made in licensing correspondence and licensee commitments documented in NRC safety evaluations).

35. In addition, the Staff may also hold licensees to perform and/or comply with licensee statements made under oath. For example, in *PFS* the Board declined to impose an intervenor's requested license conditions where the conditions at issue were statements made by the applicant "in the course of its proposed findings . . . [and] by its witnesses under oath before the Board as part of its application." *PFS*, LBP-05-21, 62 NRC at 312. The *PFS* Board found such statements indicated a commitment by the applicant to comply with the relevant safety standards and therefore "saw little purpose in repeating those assurances as license conditions." *Id.* at 311 (referencing the Commission's instruction in CLI-01-9, 53 NRC at 235, that promises and representations made to NRC Staff and NRC hearing boards are *not* rendered meaningless unless reiterated in the license). Moreover, a Board is permitted, in its decision, to include commitments made by an Applicant under oath. *See Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), LBP-00-35, 52 NRC 364, 410 (2000).

36. If in fact, statements made by a licensee under oath to the Board and Staff are false, then there is the possibility for criminal violation under 18 U.S.C. §1001 and agency enforcement actions. Such consequences provide assurance that a licensee will comply with statements made under oath. *See PFS,* LBP-00-35, 52 NRC at 410 (citing *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 & 4), ALAB-898, 28 NRC 36, 41 (1998)).

C. Staff Guidance

37. At the direction of the Commission, the Staff prepared NUREG-1801, Generic Aging Lessons Learned ("GALL") Report. *See* Memorandum from A. Vietti-Cook to W. Travers, *Staff Requirements-SECY-99-148-Credit for Existing Programs for License Renewal,* (Aug. 27, 1999) (ADAMS Accession No. ML003751930) (approving the Staff's recommendations and directing the Staff to proceed with GALL). The purpose of GALL is "to enhance the

predictability, consistency, and efficiency of NRC reviews of license renewal applications." SECY-01-0074, *Approval to Publish Generic License Renewal Guidance Documents* (July 2, 2001) (ADAMS Accession No. ML011860200).

38. The GALL provides that one way applicants may demonstrate that their aging management programs will effectively manage the effects of aging during the period of extended operation is by stating that a program is "consistent with" or "based on" GALL.

39. When an applicant states that its program is "bounded by the GALL program[ ], the staff's review will shift from reviewing each program in detail to verifying the applicant's assertion." SECY-01-0074, Memorandum from W. Travers to Commissioners, *Approval to Publish Generic License Renewal Guidance Documents,* (Apr. 26, 2001) (ADAMS Accession No. ML010990201). Thus, an applicant's statement that its program is "consistent with" or "based on" GALL is consistent with the purpose of GALL, i.e. to create predictability, consistency, and efficiency in the Staff's license renewal reviews. When an applicant makes such statements, the Staff will verify, through audits, that the applicant's programs are in fact consistent with GALL.[22]

---

[22] NUREG-1800 also provides the following guidance regarding audits:

> An audit and review is conducted at the applicant's facility to evaluate those AMRs or AMPs that the applicant claims to be consistent with the GALL Report. An audit also includes technical assessments of exceptions or enhancements to the GALL Report AMP program elements. Reviews are performed to address those AMRs or AMPs related to emergent issues, stated to be not consistent with the GALL Report, or based on an NRC-approved precedent (e.g., AMRs and AMPs addressed in an NRC SER of a previous LRA).

NUREG-1800, Standard Review Plan for License Renewal Applications for Nuclear Power Plants, Rev. 1 (Sept. 2005) at Sect. 3.0.1.

40. Although GALL is Staff guidance and therefore does not have the force of regulation, in light of its origin (i.e. it was prepared at the Commission's direction) and purpose (i.e., predictability, consistency, and efficiency of the Staff's license renewal reviews), GALL is entitled to special weight by this Board. *See Long Island Lighting Co.* (Shoreham Nuclear Power Station, Unit 1), ALAB-900, 28 NRC 275, 290 (1988), *review declined,* CLI-88-11, 28 NRC 603 (1988) (Staff guidance prepared at the direction of the Commission is entitled to special weight.); *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-01-22, 54 NRC 255, 264 (2001) (Staff guidance documents prepared to assist with regulatory compliance with the Commission's regulations are also entitled to special weight.).

D. Burden of Proof

41. In this proceeding, the overall burden of persuasion is on Entergy. *See* 10 C.F.R. § 2.325. NEC, however, must come forward with evidence that Entergy's analysis and programs are inadequate. *Louisiana Power & Light Co*. (Waterford Steam Electric Station, Unit 3), ALAB-732, 17 NRC 1076, 1093 (1983). The adequacy of the Staff's review, however, is not challenged or reviewed in this proceeding. *See* Rules of Practice for Domestic Licensing Proceedings-Procedural Changes in the Hearing Process, Final Rule, 54 Fed Reg. 33,168, 33,171 (Aug. 11, 1989) (*citing Pacific Gas and Electric Co*. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-728, 17 NRC 777, 807, *review declined*, CLI-83-82, 18 NRC 1309 (1983)). *See also Entergy Nuclear Vermont Yankee & Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), CLI-07-16, 65 NRC 371, 385 n.69 (2007) (observing that Licensing Boards lack authority to supervise or direct the Staff in its performance of

non-adjudicatory duties).[23]

IV. NEC CONTENTIONS 2A & 2B

A. Statement of Issue

42. Contentions 2A & 2B allege that the analytical techniques employed in Entergy's environmentally corrected cumulative usage factor ("CUFen") analysis were flawed by numerous uncertainties, unjustified assumptions, and insufficient conservatism, and produced unrealistically optimistic results. Therefore, NEC contended, Entergy has not, by this flawed analysis, demonstrated that the reactor components assessed will not fail due to metal fatigue during the period of extended operation.

B. Witnesses

43. During the hearing a total of four witnesses appeared: two on behalf of Entergy, one on behalf of the Staff, [24] and one on behalf of NEC. Direct testimony was submitted by Entergy, NEC, and the Staff.[25] Rebuttal testimony[26] was submitted by witnesses for Entergy

---

[23] At the hearing, references were made to an Inspector General's ("IG") report regarding the Staff's license renewal procedures. Tr. 1521-22 (J. Karlin). These statements, however, are outside the scope of license renewal because the adequacy of the Staff's review is not an issue in this proceeding. Thus, the IG report and the comments made at the hearing referring to the IG report played no part in this Board's decision-making.

[24] Staff also presented the testimony of Dr. Kenneth C. Chang in connection with its initial statement of position. *See* Staff Exh. 2. Because Dr. Chang was unable to provide live testimony due to a medical condition, the Staff moved to withdraw Dr. Chang's testimony. Tr. 721. The Board denied the Staff's motion, and admitted Dr. Chang's affidavit and exhibits. Tr. 1176. Dr. Chang's affidavit (Affidavit of Dr. Chang Concerning NEC Contentions 2A & 2B (Metal Fatigue)) was admitted as Staff Exh. 2.

[25] Joint Declaration of James C. Fitzpatrick and Gary L. Stevens on NEC Contentions 2A/2B-Enviornmentally Assisted Fatigue, Post Tr. 763 ("Fitzpatrick-Stevens Decl."); Pre-Filed Direct Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, and 4, Post Tr. 779 ("Hopenfeld Decl."); Affidavit of John R. Fair Concerning NEC Contentions 2A & 2B (Metal Fatigue), Post Tr. 768 ("Fair Affidavit").

[26] Supplemental Testimony of James C. Fitzpatrick and Gary L. Stevens on NEC Contentions (continued. . .)

and NEC.[27] All four witnesses provided oral testimony in response to questions by the Board.

44. Entergy presented the initial and rebuttal testimony of two qualified expert witnesses: Mr. James C. Fitzpatrick and Mr. Gary L. Stevens. Mr. Fitzpatrick is currently employed by Areva, NP as an Engineering Supervisor. Exh. E2-02. Prior to March of 2008, Mr. Fitzpatrick was employed by Entergy as a Senior Lead Engineer in the Design Engineering Department at Vermont Yankee. *Id.* In that capacity, Mr. Fitzpatrick provided support for Vermont Yankee's LRA in the areas of metal fatigue and flow-accelerated corrosion. *Id.* Mr. Fitzpatrick holds Bachelor of Science ("BS") and Master of Science ("MS") degrees in civil engineering and has over 30 years of experience in design, construction, and modification of nuclear power plant structures, including more than 20 years of experience in operating plant engineering support. *Id.*

45. Mr. Stevens is employed by Structural Integrity Associates ("SIA") as a Senior Associate. Exh. E2-08. Mr. Stevens has twenty-five years of experience in the nuclear energy field, specializing in the application of finite element model analysis, fracture mechanics, and structural and fatigue analyses of nuclear components. *Id.* Mr. Stevens has experience with the application of ASME Code Sections III and XI and has served on various ASME code committees and working groups. *Id.* Mr. Stevens holds BS and MS degrees in mechanical

---

(. . .continued)

2A/2B-Enviornmentally Assisted Fatigue, Post Tr. 763 ("Fitzpatrick-Stevens Supp. Decl."); Pre-filed Rebuttal Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3, and 4, Post Tr. 779 ("Hopenfeld Rebuttal").

[27] Although NEC submitted rebuttal testimony from Ulrich Witte concerning Contentions 2A & 2B, the Board found, based upon motions in limine filed by the Entergy and the Staff that Mr. Witte was not qualified to testify on Contentions 2A & 2B and struck his testimony regarding these issues. Limine Order at 15.

engineering. *Id.* Mr. Stevens supervised the SIA staff performing fatigue calculations for Vermont Yankee, reviewing all aspects of the work. Fitzpatrick-Stevens Decl., Post Tr. 763, at A18. Mr. Stevens personally performed the environmentally assisted fatigue calculation portion of the confirmatory analysis for the feedwater nozzle. *Id.*

46. The Staff presented the initial testimony of Mr. John R. Fair. Mr. Fair is employed in the Division of Engineering in the Office of Nuclear Reactor Regulation ("NRR") as a senior mechanical engineer. Fair Affidavit, Post Tr. 768, at Statement of Professional Qualifications of John R. Fair. Mr. Fair has over 35 years of experience in the nuclear power industry, including 31 years at the NRC. *Id.* Mr. Fair was involved in the development of the Staff's technical position regarding fatigue evaluation of ASME Code components and the development of NRC review criteria for license renewal fatigue calculations. *Id.* He has also served on ASME Code working groups on seismic design and component fatigue design criteria. *Id.* Mr. Fair holds BS and MS degrees in mechanical engineering. *Id.* Mr. Fair provided advice to colleagues reviewing Entergy's metal fatigue submissions and was involved in preparing Regulatory Issue Summary 2008-10 Fatigue Analysis of Nuclear Power Plant Components (Apr. 11, 2008) (Exh. NEC-JH_23). *Id.*

47. NEC presented the testimony of Dr. Joram Hopenfeld a professional consultant. Dr. Hopenfeld holds BS, MS, and PhD degrees in engineering, and has 45 years of experience in the areas of thermal hydraulics, materials, corrosion, radioactivity transportation, instrumentation, and PWR steam generator testing and accident analysis. Exh. NEC-JH_02. Dr. Hopenfeld is a former NRC employee. *Id.* Since leaving the NRC in 2001, Dr. Hopenfeld has operated a small corporation, Noverflo, which is developing fiber optic sensors for the oil, gas, and environmental monitoring industries, and has provided consulting services to law firms and citizens groups. *Id.* During his nearly 20 years at the NRC, Dr. Hopenfeld worked on

matters related to PWR steam generators. Prior to working for the NRC, Dr. Hopenfeld worked for the Department of Energy, also on matters related to steam generators. *Id.*

48. The Board found the witnesses presented by Entergy, the Staff, and NEC[28] to be qualified to present testimony on the areas they addressed. However, we accorded less weight to the testimony of Dr. Hopenfeld relating to stress analysis because, by his own admission, he is not an expert on stress analysis. Tr. 832-833 (Hopenfeld). The Board also accorded Dr. Hopenfeld's testimony less weight based on his admission that he did not know whether calculation of CUFens is a normal thing done at all nuclear power plants, Tr. 1015, and his inability to justify the results of his own CUFen analysis. Tr. 1130-32 (Hopenfeld). Furthermore, based on Dr. Hopenfeld's statement of professional qualifications, Exh. NEC-JH_02, Dr. Hopenfeld's knowledge and experience in the area of CUFen analysis appears limited at best.

C. Legal and Factual Framework for Contentions 2A and 2B

49. Resolution of NEC Contentions 2A and 2B requires an understanding of the legal and factual framework of these contentions. Therefore, this section will provide the legal and regulatory framework, and uncontested factual background and basics concerning these contentions.

1. Regulatory Requirements for Time-Limited Aging Analyses ("TLAAs")

50. Resolution of NEC Contentions 2A & 2B requires careful reading of the regulations governing TLAAs. As defined in § 54.3:

---

[28] As noted above in footnote 27, the Board found that NEC's consultant, Mr. Witte, was not qualified and his pre-filed testimony on Contentions 2A and 2B was excluded from the evidentiary record.

> *Time-limited aging analyses*, for purposes of this part, are those licensee calculations and analyses that: (1) involve systems, structures, and components within the scope of license renewal, as delineated in § 54.4(a); (2) consider the effects of aging; (3) involve time-limited assumptions defined by the current operating term, for example, 40 years; (4) were determined to be relevant by the licensee in making a safety determination; (5) involve conclusions or provide the basis for conclusions related to the capability of the system, structure, and component to perform its intended function, as delineated in § 54.4(b); *and* (6) are contained or incorporated by reference in the CLB.

(emphasis added). Accordingly, for purposes of license renewal, TLAAs are *existing* analyses that are part of the plant's CLB. They are not new analyses.

51. Section 54.21 sets forth what must be included in a license renewal application. With regard to TLAAs, § 54.21 requires that:

> Each application must contain the following information:
> . . .
> (c) An evaluation of time-limited aging analyses.
> (1) A list of time-limited aging analyses, as defined in § 54.3, must be provided. The applicant shall demonstrate that—
> (i) The analyses remain valid for the period of extended operation
> (ii) The analyses have been projected to the end of the period of extended operation; *or*
> (iii) The effects of aging on the intended function(s) *will be* adequately managed for the period of extended operation.

(emphasis added).

52. To satisfy § 54.21(c)(1), the applicant must assess and list TLAAs and demonstrate compliance with (i), (ii), or (iii). If a license renewal applicant selects § 54.21(c)(1)(i), its application must demonstrate that existing analyses are valid for 60 years. If an applicant selects (ii), its application must demonstrate that its existing analyses have been projected to 60 years, such that no further analysis or management is necessary. If the applicant "cannot or chooses not to justify or extend an *existing* TLAA," its application must list TLAAs and demonstrate that the effects of aging *will be* adequately managed for the period of extended operation pursuant to § 54.21(c)(1)(iii). 60 Fed. Reg. at 22,480 (emphasis added).

The definition of TLAA in § 54.3 and the regulatory history, cited above, make clear that license renewal applications are not required to perform new TLAAs for license renewal or extend existing TLAAs, but may in the alternative, when such analyses do not exist, manage the effects of aging so that the intended functions will be maintained in accordance with the CLB.

2. Applicable Codes and Standards

53. ASME Code Section III requires that the cumulative usage factor ("CUF"), which is the sum of the ratios of applied stress cycles (n) to the number of allowable stress cycles (N) for all of the various stress magnitudes, for Class 1 components not exceed unity (1.0). Fitzpatrick-Stevens Decl., Post Tr. 763, at A8. ASME Section III Subsection NB, Subarticle NB-3200 provides guidelines and a methodology for calculating CUFs. Tr. 811 (Stevens); Supp. Fitzpatrick-Stevens Decl., Post Tr. 763, at A13. It does not require that environmentally adjusted cumulative usage factors ("CUFens")[29] not exceed 1.0. ASME Section III, Appendix B contains guidance for preparing design specifications delineating loads and load combinations that should be satisfied by the component design. However, Appendix B is not mandatory and does not require a reduction in the fatigue curves; it merely specifies that if the reduction is necessary it should be included in the design specification. *See* Staff Exh. D (stating: "Nonmandatory Appendices provide information or guidance for the use of Section III; such references are designated by a capital letter followed by Arabic numerals").

54. The ASME Code contains air curves to be used to determine the number of

---

[29] A CUFen is a CUF that has been adjusted to reflect the effects of the reactor coolant environment on the number of stress cycles that the component can withstand. *See* Fitzpatrick-Stevens Decl., Post Tr. 763, at A9. An analysis that accounts for the effects of the reactor coolant environment is an environmentally assisted fatigue ("EAF") analysis. *Id.*

allowable cycles. Exh. NEC-JH_03 at 2. The design fatigue curves in the ASME Code were developed based on laboratory testing of specimens in an air environment. Exh. E2-03; Exh. NEC-JH_03 at 2. To produce the design curves, the best-fit curves produced from the experimental data were lowered by a factor of 2 on stress or 20 on cycles, whichever was more conservative, to account for uncertainties in relating experimental data to actual plant conditions. Exh. E2-03.

55. A CUF or CUFen of 1.0 is an acceptance criterion. Tr. 825 (Stevens). A CUF of 1.0 does not mean failure because of the conservatisms built into the process. Tr. 825, 838 (Stevens). A CUF or CUFen of less than 1.0 demonstrates acceptability. Tr. 894 (Stevens). A CUFen of .99 is acceptable because "the 1.0 criterion has margin in and of itself because of the methodology and criteria applied." Tr. 895 (Stevens). Although the definition of CUF is the sum of the ratios of the applied stress cycles over allowable cycles, the air curves used to determine the number of allowable cycles are design curves, not failure curves. Tr. 896-97 (Stevens). Rather, to create the design curves, adjustment factors were applied to bound the experimental data. *Id.* Thus, the original ASME curves bounded the experimental data that existed at that time. Tr. 899 (Fair).

56. When the CUF or CUFen is or exceeds 1.0, there is a one to five percent chance of initiating a crack that is three millimeters deep. Tr. 900-903 (Fair). This is not a failure of the component, it is just a crack. Tr. 900 (Fair).

57. Piping at Vermont Yankee was designed to American Institute of Standards ("ANSI") Code B31.1, which does not require fatigue evaluations. Tr. 889 (Fitzpatrick); Tr. 893 (Stevens); Fitzpatrick-Stevens Decl., Post Tr. 763, at A21.

3. Staff Guidance

58. The NRC Staff has performed studies of the effect of the reactor water

environment on fatigue life. Exh. E2-03. In 1995, the Staff conducted a study to determine whether to require existing plants to consider environmental effects. Tr. 1016 (Fair). Part of that study involved a risk assessment, and based upon the results of that risk assessment, the Staff determined that it could not justify requiring existing plants to consider environmental affects because of the low risk that a crack will result in failure of the component. Tr. 1016-17 (Fair); Exh. E2-03. The low risk came from an evaluation of the probability of initiating a fatigue crack if the CUF or CUFen exceeds 1.0, coupled with the probability of that fatigue crack actually growing through the component to create leakage, and the probability of that through-component crack causing the component to fail, and the consequences of component failure. Tr. 1018-19 (Fair); Exh. E2-03. The results of the risk assessment showed that the increase in the core damage frequency ("CDF"), i.e. a situation that would challenge plant safety systems, was negligible even with very high CUFs. Exh. E2-03 at 4. Although leakage due to unanticipated thermal loadings has occurred, Mr. Fair testified for the Staff that he was not aware of any failures in primary systems at nuclear power plants. Tr. 1019 (Fair).

59. Thus, in closing out Generic Safety Issue ("GSI")-190 in 1999, the Staff did not impose any additional requirements on licensees during the initial 40-year term because the risk was low and, therefore, backfitting was not justified. Exh. E2-03 at 5. The Staff did, however, recommend that license renewal applicants consider environmentally assisted fatigue when developing Aging Management Programs ("AMP"). *Id.*

60. Argonne National Laboratory ("Argonne") has produced three NUREG/CRs on metal fatigue: 5704, 6583, and 6909. Tr. 782-84 (Fair). NUREG/CR-6909 includes additional data acquired by Argonne after NUREG/CRs 5704 and 6583 were completed, Tr. 843 (Fair), and contains new air curves for determining allowable cycles and new equations for calculating Fen multipliers. Tr. 789 (Fair).

61. For license renewal, Staff guidance (NUREG-1800, "GALL" Section X.M1, Exh. E2-05) recommends that license renewal applicants use the guidance in NUREG/CR-6260 "Application of NUREG/CR-5999 Interim Fatigue Curves for Selected Nuclear Power Plant Components" (Feb. 1995) (Staff Exh. 6) to identify critical components and then apply the appropriate environmental life correction factors from NUREG/CR-6583 or 5704.

62. For new reactors, the Staff endorsed the use of NUREG/CR-6909 in Regulatory Guide 1.207. Tr. 786 (Fair). Regulatory Guide 1.207 provides that NUREG/CR-6909 only applies to new plants. Tr. 787 (Fair); Staff Exh. 13 at Item D "Implementation." Regulatory Guide 1.207 (Staff Exh. 13 at 2) specifically provides: "Because of significant conservatism in quantifying other plant-related variables such as cyclic behavior, including stress and loading rates involved in cumulative fatigue [life] calculations, the design of the current fleet of reactors is satisfactory." Tr. 791-92 (J. Karlin quoting Regulatory Guide 1.207).

4. Calculation of CUFs and CUFens

63. The purpose of CUF and CUFen calculations is to show acceptability, not margin. For that reason, fatigue analyses are performed with simplifications and conservatisms and there is no need to repeat analyses to determine if the CUF or CUFen could be lower. Tr. 894 (Stevens); Fair Affidavit, Post Tr. 768, at A4. There is no need to quantify conservatisms in fatigue evaluations if it is possible to demonstrate that all of the inputs to the analysis were conservative. Tr. 911, 913 (Stevens). When the criterion is acceptability, attempting to quantify conservatism is a meaningless exercise. Tr. 912 (Stevens).

64. Given that the goal is to show acceptability and therefore fatigue analyses are performed with simplifications and conservatisms, it follows that if the result using simplifications or conservatisms does not produce an acceptable result, it will likely be possible to obtain an acceptable result by performing a more detailed analysis. Tr. 915 (Stevens); Fair Affidavit Post,

Tr. 768, at A4. Specifically, actual plant transients are less severe than design transients, which are defined on a generic basis for all similar plants for the design of the component. Fair Affidavit Post, Tr.768, at A4. Using plant-specific operating experience with respect to the transient severity and frequency will typically result in a lower CUF value for the component. *Id*.

65. CUFs are adjusted for the environmental effects of the reactor water environment. Tr. 838-39 (Stevens). CUFen is calculated as the product of the CUF for the component and the corresponding Fen. Fitzpatrick-Stevens Decl., Post Tr. 763, at A20. The stresses, however, do not change due to the component's exposure to the reactor water environment. Tr. 839 - 40 (Stevens).

5. Entergy's Program for Managing the Effects of the Reactor Water Coolant Environment on Fatigue Life

66. Entergy presented its initial assessment of the effects of the reactor water coolant environment on fatigue life in section 4.3.3 of its LRA. Fitzpatrick-Stevens Decl., Post Tr. 763, at A19. In Table 4.3-3, Entergy provided a list of the CUFens for nine critical locations. *Id.* at A21. The locations were selected based on guidance in NUREG/CR-6260 (Staff Exh. 6). *Id.* As indicated in that table, Vermont Yankee did not have a plant-specific CUF value for each location because Vermont Yankee's piping was designed in accordance with ANSI Code B31.1, which, unlike ASME Code Section III, does not require fatigue analysis. Tr. 889 (Fitzpatrick); Tr. 893 (Stevens); Fitzpatrick-Stevens Decl., Post Tr. 763, at A21. Therefore, for locations where Vermont Yankee did not have plant-specific values, Entergy substituted values from NUREG/CR-6260 (Staff Exh. 6). Fitzpatrick-Stevens Decl., Post Tr. 763, at A21. Those locations were: the reactor recirculation piping tee, the core spray safe end, the residual heat removal return piping, and the feedwater piping. Fitzpatrick-Stevens Decl., Post Tr. 763, at A19. The CUFen values in the LRA were calculated using existing CUF values, where available, and

generic values from NUREG-6260, where not available. Tr. 891 (Fitzpatrick). Seven of the nine CUFens listed in that table exceed 1.0. Tr. 892 (Fitzpatrick).

67. In its application, Entergy stated that, with respect to locations where the CUFen would exceed 1.0 during the period of extended operation, Entergy would do one of the following: 1) refine the calculation so that the CUFen would be less than 1.0; 2) develop an inspection program; or 3) repair or replace. Fitzpatrick-Stevens Decl., Post Tr. 763, at A22 (quoting LRA Section 4.3.3. at p. 4.3-7).

68. On July 6, 2006, Entergy submitted Commitment 27 which stated that, for each location that may exceed a CUF of 1.0 when considering environmental effects, Entergy will implement one or more of the following options: (1) further refinement; (2) management of affected locations by an inspection program; (3) repair or replacement of the affected locations. Staff Exh. 1 at 4-34.

69. On July 3, 2007, Entergy revised Commitment 27 to state that it would select one of the aforementioned options at least two years prior to entering the period of extended operation. Staff Exh. 1 at 4-35. On July 30, 2007, in response to a Staff request for additional information ("RAI") about the July 3, 2007 amendments to Commitment 27, Entergy stated that it intended to comply with Commitment 27 "by demonstrating, through the implementation of Option 1 [further refinement], that the cumulative usage factors (CUF) of the most fatigue sensitive locations are less than 1.0 throughout the license renewal period, considering both mechanical and environmental effects." Staff Exh. 1 at 4-36.

70. On September 17, 2007, Entergy submitted Amendment 31 to its LRA. Staff Exh. 22. The Amendment contained the results of Entergy's refined fatigue analysis. It also amended Vermont Yankee's Fatigue Monitoring Program to include assessment of the impact of the reactor water environment on critical components and periodic review of accumulated

transient cycles and, if necessary, associated updates of fatigue usage calculations, consistent with the program described in NUREG-1801 Section X.M1 (Staff Exh. 7) at XM-1-XM-2. *See* Staff Exh. 22. This submission implemented "Option 1" of Commitment 27. Fitzpatrick-Stevens Decl., Post Tr. 763, at A24. *See also* Entergy's Reply to Response to Board Questions (July 15, 2008) at 3 (stating that Entergy performed the "Option 1" analyses prior to the hearing "so that the methodology would be clearly known"); Tr. 918 (Fitzpatrick stating that "Option 1" analyses were performed to try to resolve the issue raised by NEC's contention).

71. During the period of extended operation, Entergy will monitor piping and components of interest in accordance with Vermont Yankee's existing in-service inspection program. Fitzpatrick-Stevens Decl., Post Tr. 763, at A27. Vermont Yankee's Fatigue Monitoring Program will track plant cycles and transients to ensure that the number of transient cycles experienced by Vermont Yankee does not exceed the number of cycles and transients assumed in the fatigue calculations. Fitzpatrick-Stevens Decl., Post Tr. 763, at A27. However, consistent with Commitment 27, if monitoring suggests that the number of cycles and transients will exceed the number assumed in the calculations, Entergy will update the affected analysis, implement an NRC reviewed and approved inspection plan, or repair or replace the component. Fitzpatrick-Stevens Decl., Post Tr. 763, at A27; Staff Exh. 1 at A-9 to A-10.

6. Entergy's Fatigue Calculations

a. The Refined Analysis

72. As stated above, in its initial assessment of CUFens, Entergy took existing fatigue analyses, applied Fen factors from NUREG/CRs 6583 and 5704, and calculated CUFens greater than 1.0 for a number of components. Fitzpatrick-Stevens Decl., Post Tr. 763, at A19.

73. Entergy engaged Structural Integrity Associates ("SIA") to perform CUFen

calculations. Joint Stipulations (July 8, 2008) at ¶4. SIA began by re-calculating existing CUFs for locations and components of interest to reflect Vermont Yankee's actual operating experience. Fitzpatrick-Stevens Decl., Post Tr. 763, at A28. In addition, because Entergy did not have Vermont-Yankee specific CUF values for four critical locations, SIA had to calculate CUFs for those components for the first time. *Id.;* Tr. 893-94 (Stevens). SIA then gathered Vermont Yankee's data relevant to plant operating parameters, particularly, data on the dissolved oxygen concentration both pre and post-EPU and pre and post-hydrogen water chemistry implementation in order to calculate Fen factors. Fitzpatrick-Stevens Decl., Post Tr. 763, at A28. The final step was to calculate the CUFens. *Id.*

74. Final versions of SIA's refined CUFen calculations for Vermont Yankee were issued in August and December of 2007. Joint Stipulations (July 8, 2008) at ¶5; Entergy Exhs. E2-10 through E2-23. Entergy reported results to the NRC indicating that the CUFens for all nine (9) limiting locations were less than 1.0. Staff Exhs. 22, 8.

b. Use of the Simplified Method & the Confirmatory Analysis

75. The Staff reviewed the results of Entergy's refined analysis and expressed concern about the use of a single stress term to calculate the CUFs for the core spray, recirculation, and feedwater nozzles. Fitzpatrick-Stevens Decl., Post Tr.763, at A37; Staff Exh. 1 at 4-38 to 4-40. In calculating the CUFs for these nozzles, Entergy used a single stress term as input to a Green's Function to calculate stresses due to temperature transients. Tr. 927-29 (Stevens); Exh. NEC-JH_23. The other six of the nine critical locations were not evaluated using a single stress term. Tr. 928 (Stevens).

76. The issue was not the use of a Green's Function, which is a well-documented mathematical technique, but the use of a single stress term to generate stresses for all transients, instead of using all six stresses. Tr. 927-28, 931 (Stevens); Fair Affidavit, Post

Tr. 768, at A7. In the calculations for the core spray, recirculation, and feedwater nozzles, Entergy used one value of stress input instead of using all six stress components as input to the Green's Function. Fair Affidavit, Post Tr. 768, at 7. The Staff believes that this process requires judgment on the part of the analyst to ensure a conservative result. Fair Affidavit, Post Tr. 768, at A7; Exh. NEC-JH_23. Therefore, the Staff asked Entergy to perform a confirmatory analysis using the ASME Section III, Subsection NB-3200 methodology. Staff Exh. 1 at 4-40.

77. Entergy performed the confirmatory analysis for the feedwater nozzle, the nozzle which the Staff and Entergy agreed was Vermont Yankee's bounding nozzle (i.e. nozzle with the highest CUFen). Tr. 951-52 (Fair); Staff Exh. 1 at 4-40.

78. The confirmatory analysis for the feedwater nozzle used the same finite element model, thermal transient definitions, number of transient cycles, and water chemistry inputs as the refined analysis. Fitzpatrick-Stevens Decl., Post Tr.763, at A39.

79. The confirmatory analysis of the feedwater nozzle differed from the refined analysis in that when the thermal transient stress histories were determined, the confirmatory analysis computed six component stress histories for each transient using the ANSYS finite element computer code, whereas the refined analysis used only a single stress component developed using a Green's Function from the ANSYS results to obtain stress histories. Fitzpatrick-Stevens Decl., Post Tr.763, at A39. The confirmatory analysis also differed from the refined analysis in that in the confirmatory analysis, each of the thermal transients produced six stress components (three orthogonal components and three shear stress components). *Id*. These six components were combined to obtain a maximum stress intensity history for every evaluated transient. *Id*. In the refined analysis, however, only the maximum stress difference was used. *Id*. The confirmatory analysis used all six stress components thereby "correcting" for the use of the single stress term in the refined analysis. Tr. 931 (Stevens).

80. The confirmatory analysis differed from the refined analysis in an additional respect: the confirmatory analysis used a transient-specific Fen value for each load pair, whereas, the refined analysis used a single bounding Fen value applied to the total CUF result from all load pairs. *Id*. Although the Staff does not take the position that using a specific Fen value for each transient is unacceptable (Tr. 1139 (Fair)), because of this change, the Staff was unable to make a judgement that the same level of reduction in the overall Fen value would apply to the core spray and recirculation nozzles. Tr. 925, 947 (Fair). Thus, the Staff asked Entergy to apply the original bounding Fen to the CUF computed for the feedwater nozzle in the confirmatory analysis. Tr. 1139 (Fair).

81. The results below show the CUF for the feedwater nozzle was lower in the confirmatory analysis, however, when the bounding Fen value was applied to that CUF the CUFen was higher than in the refined analysis. Thus, the CUFen analysis was bounding but, the CUF analysis was not. Tr. 924-25 (Fair). Therefore, the Staff concluded that Entergy must perform confirmatory analyses for the core spray and recirculation nozzles.

	Refined Analysis	Confirmatory Analysis
CUF	0.064	0.089
CUFen	0.639	0.353
CUFen using bounding Fen	0.639	0.893

Summary of Results from Fitzpatrick-Stevens Decl., Post Tr.763, at A40-41.

82. Entergy will be required by license condition to complete confirmatory analyses for the reactor recirculation and the core spray nozzle locations. Staff Exh. 1 at 1-2 & 4-43.

D. Factual Findings on Key Contested Issues

83. Having set forth the regulatory standards, the applicable codes, the Staff's guidance on metal fatigue, and the basic factual framework of Entergy's fatigue monitoring

program and CUFen calculations, the Board now turns to the key issues raised by NEC's contentions.

1. CUF Calculations

a. Use of the Green's Function

i. Evidence

84. Like the Staff, NEC had concerns about Entergy's use of the simplified method to calculate CUFs for the recirculation, core spray, and feedwater nozzles. *See* Exh. NEC-JH_03 at 17-18. As discussed above, Entergy performed a confirmatory analysis of the feedwater nozzle (the nozzle with the highest CUFen) showing acceptable results, but the Staff, for the reasons stated above in Section C.6.b, plans to impose a license condition requiring Entergy to also perform a confirmatory analysis for the recirculation and core spray nozzles. Dr. Hopenfeld testified that he is satisfied with the method Entergy used to calculate the CUF for the feedwater nozzle in the confirmatory analysis. Tr. 934 (Hopenfeld). Dr. Hopenfeld testified that he is satisfied that Entergy has eliminated the Green's Function simplification from its analysis of the feedwater nozzle. Tr. 936 (Hopenfeld).

85. NEC did not provide any evidence contradicting the Staff's and Entergy's position that it is reasonable to believe that the results of the confirmatory analyses of the CUFen for the core spray and recirculation nozzles Entergy will be required by license condition to perform will be acceptable (i.e. less than 1.0). *See* Exh. NEC-JH_03 at 18-19; Fair Affidavit Post, Tr. 768, at A8; Fitzpatrick-Stevens Decl., Post Tr. 763, at A43.

ii. Board Finding

86. The Board finds that the proposed license condition requiring Entergy to perform confirmatory analyses for the recirculation and core spray nozzles addresses NEC's concerns about the use of the Green's Function.

b. Number of Transients

i. Evidence

87. NEC questioned Entergy's assumption about the number of transient cycles Vermont Yankee will experience during the extended period of operation. Specifically, NEC asserted that Entergy's assumptions about the number of transient cycles Vermont Yankee will experience during the extended period of operation are incorrect and non-conservative. Exh. NEC-JH_03 at 17.

88. Entergy's expert testified that the number of transients assumed in the analysis was more than the predicted number. Fitzpatrick-Stevens Decl., Post Tr. 763, at A30. Mr. Fitzpatrick explained, for example, that Vermont Yankee's original design specification included two hundred (200) start-up/shutdown cycles. Three hundred (300) start-up/shutdown cycles were assumed in the environmentally assisted fatigue analysis performed for the LRA, but only about 93-95 cycles have actually occurred in thirty-plus years of operation, and only one hundred-sixty (160) are predicted to occur in sixty (60) years of operation. Tr. 859-60 (Fitzpatrick); *see also* Supp. Fitzpatrick-Stevens Decl., Post Tr. 763, at A17.

89. Entergy's experts also testified that the design basis transient severity definitions, as opposed to (lesser) actual transient severities were used in Vermont Yankee's fatigue calculations. *Id.* Mr. Stevens testified that Entergy/SIA used the transient definitions specified by the plant's designer which are very conservative because they assume abrupt changes in temperature and flow. Tr. 852-53 (Stevens). In addition, SIA assumed that all transients occurred under extended power uprate conditions. Tr. 856, 869-70 (Stevens). The actual transients experienced by the plant are much less than those assumed in the design, Tr. 852 (Stevens), and Vermont Yankee has never experienced a thermal transient more severe than the design basis. Tr. 1170 (Fitzpatrick).

90. Dr Hopenfeld asserted that Entergy should not have assumed that the number of transients would be linear with time, but instead should have multiplied the number of expected transients by a minimum of 1.2 to account for additional unanticipated transients due to the 20% EPU. Exh. NEC-JH_03 at 17. Entergy responded that it did not assume that the number of transients is linear with time. Rather the transients used in the CUFen analyses are a combination of design transients and additional, more detailed design conditions from a later BWR 4 design specification. Fitzpatrick-Stevens Decl., Post. Tr.763, at A.55.

91. Dr. Hopenfeld responded to Entergy's claims of conservatism in the assumed number of transients by testifying that he could not conclude whether the number of transients Entergy used in its analysis was conservative unless he could quantify the degree of conservatism (Tr. 865 (Hopenfeld)), and he had not been given enough information to do so. Hopenfeld Rebuttal, Post Tr. 779, at A21; Tr. 866-67 (Hopenfeld).

92. Also on the topic of transients, Dr. Hopenfeld opined that the bathtub curve, a traditional curve for failures, could apply to Vermont Yankee, and if it did the number of transients might increase due to aging and the Extended Power Uprate ("EPU"). Tr. 867-69 (Hopenfeld). Mr. Stevens responded that there is no field evidence supporting the bathtub effect. Tr. 870-71 (Stevens). In the case of Vermont Yankee, the frequency of start-up/shutdown cycles is half what it used to be. Tr. 871 (Stevens). Throughout the US nuclear fleet, including plants operating at EPU levels, plants trip much less often now than they did in the past due to improvements in maintenance, inspections, etc. Tr. 871-72 (Stevens). Thus experience shows that it is conservative to project transients linearly. Tr. 871-72 (Stevens). In any event, Vermont Yankee will be monitoring the number of transients that occur against its assumptions and take corrective action if needed. Tr. 872 (Stevens); Tr. 873-74 (Fitzpatrick). Tracking cycles in this manner is a way of verifying the assumptions in CUFen calculations.

Tr. 1145 (Fair).

ii Board Finding

93. The Board finds that Entergy's assumptions about the number and severity of transients Vermont Yankee will experience during the period of extended operation are conservative.

c. Heat Transfer Equations

i. Evidence

94. NEC, through Dr. Hopenfeld, challenged the heat transfer coefficients Entergy used in its fatigue analysis to calculate thermal stress for each transient. Exh. NEC-JH_03 at 12-15; Tr. 1096-05 (Hopenfeld). He asserted that Entergy inappropriately used location-independent heat transfer coefficients. Exh. NEC-JH_03 at 15. Dr. Hopenfeld testified that Entergy incorrectly used a heat transfer equation for the feedwater nozzle that is only applicable to fully developed turbulent flow. *Id* at 12-14. Using that equation was incorrect because the flow in Vermont Yankee's three feedwater nozzles is not fully developed as there are only 48 inches of horizontal pipe upstream of the nozzle. *Id.*; Hopenfeld Rebuttal, Post Tr. 779, at A16 (citing Exh. NEC-JH_29); Tr. 1120-21 (Hopenfeld).

95. Mr. Stevens refuted Dr. Hopenfeld's assertion that the flow is not fully developed referencing Dr. Hopenfeld's exhibit, NEC-JH_29, a two page excerpt from the textbook: E.R.G. ECKHERT, HEAT AND MASS TRANSFER (2d ed. 1959). Mr. Stevens testified that Figure 8-9 on page 212 of the textbook is not applicable to the geometry and conditions at Vermont Yankee. First, the geometry is not applicable because it assumes a pipe entrance; at Vermont Yankee the discontinuity is an elbow, not a pipe entrance, which has less impact on flow. Tr. 1124-25 (Stevens). Second, as the graph shows, the effects of the pipe entrance decreases as the velocity of the fluid increases. Tr. 1125 (Stevens). The velocity at Vermont Yankee is well off

the chart in Figure 8-9 on page 212 of Exh. NEC-JH_29. Tr. 1125-26 (Stevens). Therefore using a heat coefficient applicable to fully developed flow was appropriate. Tr. 1126 (Stevens).

96. Dr. Hopenfeld asserted that it was incorrect for Entergy to assume a constant heat transfer coefficient because, as you go circumferentially around the nozzle, the flow field may be larger at the top of the nozzle than at the bottom, thus making the heat transfer coefficients different as you go around. Tr. 1110-1111 (J. Reed summarizing Hopenfeld's argument with Hopenfeld indicating agreement). Entergy's expert, Mr. Stevens, responded that while he agreed that heat transfer is a function of velocity and temperature and that it is necessary to account for temperature and velocity, the higher the heat transfer coefficient applied, the more conservative the stress results. Tr. 1111 (Stevens). This is because the larger the temperature differentials, the higher the thermal stress. *Id.*

97. Mr. Stevens explained that in doing the fatigue calculations for Vermont Yankee using the simplified method he selected the highest flow rate to compute the heat transfer coefficients and used that value for all transients. Tr. 1113 (Stevens); Fitzpatrick-Stevens Decl., Post, Tr. 763, at A39. However, in the confirmatory analysis Entergy/SIA did not use a constant heat transfer coefficient. Tr. 1116 (Stevens). Rather, the heat transfer coefficient varied as a function of temperature and flow rate during each transient. Tr. 1116 (Stevens); Fitzpatrick-Stevens Decl., Post Tr.763, at A39 (describing differences between the treatment of thermal stresses in the refined and the confirmatory analyses), A54 (responding to Dr. Hopenfeld's arguments regarding heat transfer equations in Exh. NEC-JH_03 at 12-15). Mr. Stevens further testified that given the conditions at Vermont Yankee, Dr. Hopenfeld's assertion that the temperature would vary as you go azimuthally around the nozzle was not applicable. Tr. 1119 (Stevens).

98. Mr. Stevens also testified that the thermal sleeve on Vermont Yankee's

feedwater nozzle, which has been in place since 1976, (Tr. 958 (Fitzpatrick)), is very beneficial because it reduces the severity of the transients on the nozzle. Tr. 957 (Stevens).
Dr. Hopenfeld's testimony on heat transfer coefficients and the severity of thermal transients does not mention the impact of the thermal sleeve. *See* Exh. NEC-JH_03; Hopenfeld Rebuttal, Post Tr.779, at A16-18.

ii. Board Findings

99. The Board finds that Entergy's fatigue calculations use appropriate heat transfer coefficients. Consequently, NEC has failed to demonstrate that the equations used by Entergy in its fatigue analyses were inappropriate.

100. The Board further notes that Dr. Hopenfeld testified that he does not object to the method Entergy used to determine stresses (Tr. 815 - 16 (Hopenfeld)) or to calculate cumulative usage factors (i.e. fatigue) (Tr. 833 (Hopenfeld)), and that he further testified that he has no dispute with how Entergy handled strain, Tr. 1038 (Hopenfeld). Therefore, the Board resolves all of NEC's challenges to the method Entergy used to calculate CUFs in Entergy's favor.

2. Alleged Use of Out-Dated Fen Equations

a. Evidence

101. NEC asserted that Entergy should have used the ASME Code design curves and the Fen equations in NUREG/CR-6909 in its CUFen analysis because the Fen equations in NUREG/CRs-6583 and 5704 are out of date. *See, e.g.*, Exh. NEC-JH_03 at 10. NEC, through Dr. Hopenfeld, asserted that Entergy should use the bounding Fen values of 12 for stainless steel and 17 for carbon steel in NUREG/CR-6909 to calculate CUFens in order to account for the many factors that can affect fatigue life. Hopenfeld Rebuttal, Post Tr. 779, at A5 p.4.
Dr. Hopenfeld further testified that NUREG/CR-6909 only provides less conservative results if the entire procedure in NUREG/CR-6909 is used, i.e. the air curves and the Fen equations.

Hopenfeld Rebuttal, Post Tr. 779, at A6. He, however, does not advocate using the air curves in NUREG/CR-6909 because they have not been incorporated into the ASME Code and therefore, the ASME Code air curves must be considered the best representation of fatigue life in air until they are adopted by ASME. Hopenfeld Rebuttal, Post Tr. 779, at A6.

102. As discussed above in Section C.3, the Staff has not endorsed the use of the fatigue curves and Fen equations in NUREG/CR-6909 for use by license renewal applicants, but has endorsed the use of the ASME fatigue curves and the Fen equations in NUREG/CRs-6583 and 5704 for use by license renewal applicants.

103. The Staff testified that its guidance for license renewal applicants is generally more conservative than the guidance in NUREG/CRs-6909, particularly for carbon and low-alloy steels. Fair Affidavit, Post Tr. 768, at A5. Mr. Fair explained that the new air curves in NUREG/CR-6909 are based on a 95-95 confidence statistical evaluation. Tr. at 790 (Fair). He explained that in performing the statistical analysis of the air test data for NUREG/CR-6909, Argonne determined that the ASME curves for carbon and low alloy steel were overly conservative and developed new air curves that are less conservative than the ASME curves. Tr. 849-50 (Fair). Instead of developing new air curves, they (the NRC and Argonne) could have divided the Fen factors by about 1.7. Tr. 850 (Fair). *See* also NUREG/CR-6909 (Exh. E2-30) at 78 (stating that the ASME Code curve adjustments for material variability, data scatter, specimen size, surface finish, and loading history, contain at least a factor of 1.7 conservatism). In other words, if the analyst uses the ASME air curves and the Fen equations in NUREG/CR-6909 he or she should divide the resulting CUFen by 1.7. Tr. 850 (Fair).

104. Mr. Fair further testified that Appendix A of NURG/CR-6909 contains comparisons of the ASME Code design curves for carbon steel and low-alloy steels in air with

the new curves developed by Argonne and shows that the ASME curves are somewhat conservative. Exh. NEC-JH_26 at A3 (carbon steel), A4 (low alloy steel); Tr. 899 (Fair). Thus, if one were to calculate CUFens for carbon or low alloy steel components using the air curves and the Fen formulas in NUREG/CR-6909, and compared it to CUFens calculated using earlier NUREGs, one would find that the CUFens calculated in accordance with NUREG/CR-6909 are lower. Tr. 796-97 (Fair). In other words, NUREG/CRs 6583 and 5704 give more conservative results. Tr. 797, 844 (Fair); Tr. 805-06 (Stevens).

105. Entergy's expert, Mr. Stevens, testified that he calculated the CUFens for the nine (9) critical locations at Vermont Yankee using the fatigue curves and the Fen equations in NUREG/CR-6909. Tr. 801 (Stevens). In all cases the CUFen calculated using the NUREG/CR-6909 procedures was lower than the CUFen calculated using the ASME air curves and the Fen equations in NUREG/CRs 6583 and 5704. Tr. 799-800 (Stevens).

b. Board Findings

106. The Board finds that NEC has failed to show that Entergy's use of the ASME fatigue curves and the Fen equations in NUREG/CRs 6583 and 5704 is inadequate. Based upon the evidence presented, the Board finds NEC's argument that Entergy should be required to use the ASME fatigue curves and the Fen values in NUREG/CR-6909 unpersuasive. Furthermore, Dr. Hopenfeld's assertion that use of the ASME fatigue curves and the Fen values in NUREG/CR-6909 would be a better or more conservative approach is unpersuasive in light of the testimony that CUFens calculated using NUREG/CR-6909 procedures are less conservative than CUFens calculated using the ASME fatigue curves and the Fen equations in NUREG/CRs 5704 and 6583.

3. Alleged Failure to Consider Factors Known to Affect Fatigue Life

107. NEC's contention alleges that Entergy did not properly consider various factors

that affect fatigue life. In his rebuttal testimony, Dr. Hopenfeld presented a table of thirteen uncertainties he asserts Argonne failed to include either in its 1998 equations (NUREG/CRs 6583 and 5704) or its 2007 (NUREG/CR 6909) equations. Hopenfeld Rebuttal, Post Tr. 779, at A5 pp.4-6.

108. The Board asked Dr. Hopenfeld to identify his top three concerns. Tr. 1012-14. Dr. Hopenfeld identified: 1) cracks in the cladding (existing surface cracks); 2) surface finish; and 3) oxygen. Tr. 1013-14 (Hopenfeld). We will address Dr. Hopenfeld's top three concerns individually, and the remaining uncertainties collectively.

a. Cracks in Cladding

i. Evidence

109. Dr. Hopenfeld testified that Entergy failed to consider cracks in the cladding in its fatigue analysis. Tr. 1053-54; Hopenfeld Rebuttal, Post Tr. 779, at A15. He testified that whereas some plants have removed the cladding inside the feedwater nozzle, Vermont Yankee has not. Tr. 1040 (Hopenfeld). Cracks in the cladding, Dr. Hopenfeld asserted, could provide sites for accelerated corrosion, thereby accelerating failure under cycling loads. Tr. 1054 (Hopenfeld); Hopenfeld Rebuttal Post, Tr. 779, at A15. Dr. Hopenfeld did not, however, have any evidence that there are cracks in the feedwater nozzle cladding; he was just suggesting a possible uncertainty. Tr. 1064 (Hopenfeld).

110. Mr. Fitzpatrick testified for Entergy that when cracks in the cladding were discovered at other plants, Vermont Yankee inspected the cladding in its feedwater nozzle and ground out indications of cracking. Tr. 1041 (Fitzpatrick). They also performed penetrant testing ("PT") to identify cracks. Tr. 1042 (Fitzpatrick). Entergy now performs ultrasonic inspections to look for cracks. *Id*.

111. Entergy has postulated a crack in the cladding and has performed an ASME

Section XI analysis. Tr. 1044 (Fitzpatrick). The analysis shows how the postulated crack would grow with time, and Vermont Yankee's inspection program is designed with this analysis in mind. Tr. 1049 (Fitzpatrick). Entergy's program for inspecting Vermont Yankee's feedwater nozzle has not detected any cracks in the past 20 years. Tr. 1052 (Fitzpatrick).

112. Although Entergy has postulated a crack and has performed an ASME Section XI analysis, Entergy does not postulate a crack in the fatigue analysis, which is performed under ASME Section III. Tr. 1052 (Fitzpatrick). Section III analysis does not require the analyst to postulate cracks. Tr. 1052 (Fitzpatrick); Tr. 1059 (Stevens). Section III deals with fabrication of vessels and requires repair if there are any indications of cracking. Tr. 1059 (Stevens).

113. Entergy has a "belt and suspenders" approach to cracking: an ASME Section XI program that continues to inspect all four feedwater nozzles every four cycles, and a Section XI analysis of a postulated crack demonstrating that a crack will not grow to an unacceptable size during the life of the plant. Tr. 1060-61 (Stevens); *see also* Tr. 1062 (Fitzpatrick) (stating that 100% UT inspections of the feedwater nozzles are performed every four cycles); Fitzpatrick-Stevens Decl., Post Tr. 763, at A53. In short, Entergy's monitoring and maintenance program ensures that cracks will have no influence on CUFens. Tr. 1061 (Stevens).

ii. Board Findings

114. The Board finds that Entergy has appropriately considered the possibility of cracks in the cladding inside the feedwater nozzle. Entergy will continue to inspect the feedwater nozzle during the period of extended operation in accordance with its existing in-service inspection program and will take corrective actions if a crack is identified. The Board further finds that, contrary to NEC's assertion, there is no ASME Code requirement to consider cracks in cladding in CUFen analyses and that Entergy appropriately considered the potential for cracking of the cladding by performing an evaluation to demonstrate that a potential crack

would not grow to an unacceptable size during the period of extended operation.

b. Surface Finish

i. Evidence

115. Dr. Hopenfeld testified that Entergy failed to consider surface finish of the components evaluated in determining Fen factors. Exh. NEC-JH_03 at 11-12. Dr. Hopenfeld referred the Board to the table on page 76 of NUREG/CR-6909. Tr. 1070-71 (Hopenfeld). He testified that the table shows that for surface finish, the ASME Code recommends adjustment by a factor of four, whereas NUREG/CR-6909 recommends an adjustment of 2.0 to 3.5 for surface finish. Tr. 1075 (Hopenfeld). Dr. Hopenfeld then suggested that while the authors of NUREG/CR-6909 are trying to say that the ASME Code is conservative, they are just making a judgment. Tr. 1077-78 (Hopenfeld). Dr. Hopenfeld further testified that because Argonne was using test specimens in a laboratory, he does not think that they fully considered the effects of surface roughness and therefore there is uncertainty in the adjustment for surface roughness. Tr. 1082-84, 1087 (Hopenfeld); Exh. NEC-JH_03 at 11.

116. Mr. Fair responded that the right hand column of the table on page 76 of NUREG/CR-6909 represents Argonne's latest assessment of the available literature in light of current data and that Argonne is suggesting an adjustment to the fatigue air curves. Tr. 1079 (Fair). The other column represents the existing ASME Code adjustment to the air curve and illustrates that the existing ASME Code air curve is more conservative. Tr. 1079 (Fair). Entergy used ASME Section III air curves to perform its calculations (Tr. 1080 (Stevens)), and surface finish is already accounted for in the air curves so there is no need to consider surface finish again in the Fen. Tr. 1089-90 (Stevens); Fitzpatrick-Stevens Decl., Post Tr. 763, at A52.

ii. Board Findings

117. The evidence shows that the effects of surface finish on fatigue life are

accounted for in the ASME air curves, which Entergy used in its fatigue analyses. Thus, the Board finds that NEC's assertion that Entergy's fatigue calculations did not properly consider surface finish lacks merit.

c. Oxygen

i. Evidence

118. Dr. Hopenfeld testified for NEC that Entergy's Fen parameters did not appropriately account for changes in oxygen concentrations due to unanticipated changes in water chemistry (oxygen excursions). Exh. NEC-JH_03 at 16. He asserted that Entergy did not use a conservative value for dissolved oxygen for carbon steel. Tr. 974, 987 (Hopenfeld). In support of his assertion, Dr. Hopenfeld pointed to NUREG/CR-6909, Exh. E2-30 at A-5, which states that for "carbon and low alloy steels, the dissolved oxygen ("DO") content associated with a stress cycle is the highest oxygen level in the transient, and for austenitic stainless steels, it is the lowest oxygen level in the transient. A value of 0.4 ppm for carbon and low alloy steels and 0.05 ppm for austenitic steels can be used for DO content to perform a conservative evaluation." Tr. 977 (Hopenfeld) (quoting NUREG/CR-6909 at A-5). Dr. Hopenfeld further asserted, based on the graph of Fen versus temperature for carbon steel on page 4-18 of MRP-47 (Exh. NEC-JH_46) that the Fen factor for oxygen is about 80 at 550 degrees Fahrenheit. Tr. 986 (Hopenfeld).

119. Entergy's experts described how oxygen concentration was considered in the fatigue analyses. Entergy provided SIA with oxygen values representative of 13 years of operation at Vermont Yankee and SIA took a bounding value. Tr. 954 (Stevens); Fitzpatrick-Steven Decl., Post Tr. 763, at A56; Exh. E2-09 at Attachment 2. Vermont Yankee uses hydrogen water chemistry. Tr. 954 (Stevens). "Hydrogen water chemistry" is a method to bring plant water chemistry under control and reduce dissolved oxygen which is detrimental to carbon

and low alloy steels. Tr. 954-55 (Stevens).

120. In its calculations, Entergy used a single value for dissolved oxygen in all transients. Tr. 973 (Fitzpatrick). The number was an average of measured oxygen levels plus one standard deviation. Tr. 974 (Fitzpatrick); Fitzpatrick-Stevens Decl., Post Tr. 763, at A56. Entergy uses the EPRI BWRVIA model to determine oxygen levels at different locations in the reactor. Tr. 1031 (Fitzpatrick). The value was 50 ppb (.05 ppm) for feedwater oxygen. Tr. 974 (Fitzpatrick). Mr. Fitzpatrick testified that once the system is stable, the oxygen content does not change very much, even during transients. Tr. 974 (Fitzpatrick).

121. Mr. Fair testified for the Staff that the oxygen content Dr. Hopenfeld referenced from NUREG/CR-6909 is suggested if an analyst using the NUREG/CR-6909 procedures does not have dissolved oxygen input. Tr. 998 (Fair). Vermont Yankee has dissolved oxygen inputs. *See supra* ¶120.

ii. Board Finding

122. The Board finds that Entergy properly considered the effects of dissolved oxygen concentration on fatigue life.

d. Other Uncertainties

i. Evidence

123. With regard to the other ten items in Dr. Hopenfeld's table of uncertainties, Hopenfeld Rebuttal, Post Tr. 779, at A5 pp.4-6, Mr. Stevens testified that contrary to Dr. Hopenfeld's assertion that the uncertainties were not addressed, all but two were either directly or inherently addressed in the analysis. Tr. 1095 (Stevens). The two that were not included in Entergy's/SIA's fatigue analyses were existing cracks in the cladding and trace impurities. Tr. 1095-96 (Stevens).

ii. Board Findings

124. The evidence does not support NEC's assertion that Entergy failed to consider important factors affecting fatigue life. Therefore, the Board finds that Entergy appropriately considered the various factors affecting fatigue life.

4. Dr. Hopenfeld's CUFen Recalculation

a. Evidence

125. In support of NEC's assertion that Entergy's CUFen calculations contained errors and were overly optimistic, Dr. Hopenfeld performed his own CUFen calculations for the nine components identified in Entergy's LRA. Exh. NEC-JH_03 at 19-21. In his calculations, Dr. Hopenfeld used the "conservative CUFs" Entergy provided in its LRA and multiplied them by the bounding Fen values on NUREG/CR-6909, which are "appropriate and conservative." *Id.* at 20. The results showed CUFens ranging from 0.38 for the residual heat return piping to 13.77 for the recirculation outlet nozzle. Exh. NEC-JH_03 at 20; Tr. 1129 (J. Reed).

126. Entergy's expert, Mr. Stevens, testified that Dr. Hopenfeld's approach to calculating CUFens was unduly conservative because he used the CUF values Entergy provided in Table 4.3-3 of its LRA. Fitzpatrick-Stevens Decl., Post Tr. 763, at A62. As noted in that table, some of those CUF values were generic values from NUREG/CR-6260 for B.31.1 piping, not Vermont Yankee-specific values, and thus did not reflect actual plant conditions and transients. *Id.* When Entergy later calculated CUFs, it used actual plant conditions and transients. *Id.*

127. The Board questioned Dr. Hopenfeld about his calculations of CUFen in the table on page 20 of his initial testimony. Tr. 1128 (J. Reed referring to Exh. NEC-JH_03 at 20). The Board asked Dr. Hopenfeld: based on the definition of CUFen, if the 60-year CUFen of a component at Vermont Yankee is 13.77, should not the component fail in 4.63 years?

Tr. 1129-30 (J. Reed). His response was "I don't know, I don't know how to relate these numbers." Tr. 1130 (Hopenfeld). He also stated that he was not predicting failure, but when the number approaches 1.0 "you have got to do something." Tr. 1132 (Hopenfeld). Dr. Hopenfeld testified that his CUFen calculations are based on his best understanding of the ASME Code and existing guidance. Tr. 1132 (Hopenfeld). Dr. Hopenfeld, however, was unable to explain why if his CUFen calculations were correct, Vermont Yankee had not experienced a failure. Tr. 1132-33. Dr. Hopenfeld did agree that his CUFen calculations were highly dependent on his selection of Fen values. Tr. 1133 (Hopenfeld).

128. The Board asked Dr. Hopenfeld why he selected Fen values of 17 for carbon and low alloy steels and 12 for stainless steel. Tr. 1133 (J. Wardwell). Dr. Hopenfeld testified that his technical basis for selecting 17 and 12 was the abstract to NUREG/CR-6909, Tr. 1134 (Hopenfeld), specifically, the statement on page iii of the abstract: "Under certain environmental loading conditions, fatigue lives in water relative to those in air can be a factor of 12 lower for austenitic stainless steels, 3 lower for Ni-Cr-Fe alloys, and 17 lower for carbon and low-alloy steels." Exh. NEC-JH_26.

129. Both the Staff and Entergy testified that Dr. Hopenfeld's use of the "bounding" Fen values from NUREG/CR-6909 without also using the air curves in NUREG/CR-6909 was inappropriate because the Fen values in NUREG/CR-6909 were designed to be used with the air curves in NUREG/CR-6909, not the ASME Code air curves. Fitzpatrick-Stevens Decl., Post Tr. 763, at A50, A62; Fair Affidavit, Post Tr. 768, at A6. Dr. Hopenfeld provided no credible evidence to support his view that the ASME code curves should be used with the Fen equations in NUREG-6909.

130. The Staff further testified that NUREG/CR-6909 does not recommend using the bounding values for fatigue evaluations. Fair Affidavit Post Tr.768, at A6.

131. Entergy's expert, Mr. Stevens, further testified that NUREG/CR-6909 states at page 3 that the correction factor of 17 for carbon and low-alloy steel is only applicable to "certain environmental and loading contentions" and those environmental and loading conditions do not exist at Vermont Yankee. Fitzpatrick-Stevens Decl., Post Tr. 763, at A50.

b. Board Findings

132. The Board finds that Dr. Hopenfeld's CUFen analysis relies in part on non-Vermont Yankee specific CUF values, employed unjustified and overly conservative assumptions, producing unrealistic results because, if at all accurate, a failure should have occurred years ago. The Board finds Dr. Hopenfeld's CUFen analysis unreliable and gives it little or no credit.

E. Summary of Board Findings of Fact on NEC Contentions 2A & 2B

133. In summary, the Board makes the following factual findings with regard to NEC Contentions 2A and 2B based on all of the evidence presented.

134. Entergy has completed option 1 of Commitment 27 by performing revised analyses. Also consistent with Commitment 27, if Entergy's monitoring program indicates a potential condition outside the bounds of the refined analysis, Entergy will 1) update or refine the affected analysis; 2) with NRC review and approval, implement a program for periodic nondestructive examination of affected locations; 3) repair or replace affected locations before the CUFen exceeds 1.0.

135. Entergy's fatigue monitoring program is consistent with the guidance in NUREG-1801, GALL. In accordance with that guidance, Entergy has elected, as a corrective action, to perform refined analyses for critical components and will monitor fatigue through cycle counting to ensure that the number of actual cycles does not exceed the number of cycles assumed in the refined calculations.

136. Entergy did not have existing CUF TLAAs for four locations (reactor recirculation piping tee, core spray safe end, residual heat return piping, and feedwater piping) and did not have existing CUFen TLAAs for any components.

137. CUFen calculations performed consistent with ASME design curves and the Fen equations in NUREG/CRs-6583 and 5704 are acceptable.

138. NEC has failed to demonstrate CUFens calculated using the Fen equations in NUREG/CRs-6583 and 5704 are inadequate. Consequently, NEC's assertion that Entergy must use the ASME air curves and the Fen equations in NUREG/CR-6909 lacks merit.

139. Entergy has demonstrated that the inputs to its fatigue calculations were appropriate and conservative. Testimony from NEC's expert, Dr. Hopenfeld, that there are uncertainties in CUF and CUFen calculations does not demonstrate either that Entergy's assumptions are unjustified or that the results are not appropriate.

140. Dr. Hopenfeld was unable to justify or otherwise explain the results of his CUFen recalculations. In the absence of such a justification or explanation, the Board concludes that they have no basis and can be given no credit.

F. Board Conclusions of Law on NEC Contentions 2A & 2B

141. The Licensing Board has considered all of the evidence presented by the parties on NEC Contentions 2A & 2B and the hearing record, consisting of the filings of the parties in this proceeding, the orders issued by this Board, the exhibits received in evidence and the transcript of the proceeding. Based on a review of the entire record in this proceeding, consideration of the proposed findings of fact and conclusions of law submitted by the parties, and based upon the findings of fact set forth above, which are supported by reliable, probative

and substantial evidence in the record, the Board has decided all matters in controversy concerning these contentions in favor of Entergy and reaches the following conclusions.[30]

142. As defined for purposes of license renewal in § 54.3, TLAAs include only those calculations and analyses that are contained or incorporated by reference into the plant's CLB. Therefore only those TLAAs contained or incorporated by reference in a plant's CLB must be evaluated under § 54.21(c).

143. Pursuant to 10 C.F.R. § 54.21(c)(1), license renewal applicants are required to provide an assessment of and list all time-limited aging analyses as defined in § 54.3, and must demonstrate either (i) that those analyses will remain valid for the period of extended operation, (ii) that those analyses have been extended to the end of the period of extended operation, or (iii) that the effects of aging on the intended functions of the components will be adequately managed for the period of extended operation.

144. Pursuant to 10 C.F.R. § 54.29, as pertinent here, a renewed license may not be issued unless actions have been identified and have been taken or will be taken with respect to metal fatigue such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB.

145. Because Vermont Yankee did not have existing CUF TLAAs for four locations and did not have existing CUFen TLAAs (i.e., no existing TLAAs to extend to the end of the period of extended operation), Entergy choose to demonstrate that the effects of aging on the intended function of components at Vermont Yankee will be adequately managed for the period

---

[30] Because Contentions 2A & 2B are resolved in Entergy's favor, Contention 2, which had been held in abeyance, is dismissed.

of extended operation.

146. To fulfill the requirement of § 54.21(c)(1)(iii), Entergy proposed a fatigue monitoring program that is consistent with the Staff's guidance in the GALL Report, NUREG 1801 Section X.M1 (Exh. E2-05). Consistent with that guidance, Entergy performed refined and confirmatory CUFen analyses. Entergy will be required by license condition to perform two additional confirmatory analyses at least two years prior to the period of extended operation.

147. Entergy has demonstrated that the inputs to its fatigue calculations were appropriate and conservative, and the resulting CUFens are less than 1.0. Testimony from NEC's expert, Dr. Hopenfeld, that there are uncertainties in CUF and CUFen calculations, does not demonstrate either that Entergy's assumptions are unjustified or that the results are not conservative.

148. Thus, as required by § 54.21(c)(1), Entergy has demonstrated that the effects of aging on the intended functions of the components will be adequately managed in accordance with § 54.21(c)(1)(iii). Accordingly, there is reasonable assurance that actions have been indentified and have been and will be taken to ensure that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB.

149. All issues, motions, arguments, or proposed findings presented by the parties, but not addressed herein have been found to be without merit or unnecessary for the Board's decision on Contentions 2A and 2B.

V. NEC CONTENTION 3

A. Statement of Issue

150. NEC's original Contention 3 stated that "Entergy's License Renewal Application does not include an adequate plan to monitor and manage aging of the steam dryer during the

period of extended operation." LBP-06-20, 64 NRC at 187. This contention was subsequently narrowed by this Board's summary disposition order. *See* NEC 3 SD Order. Thus, the specific issues before this Board with regard to Contention 3 are: 1) whether "Entergy's assessment of the monitoring data collected from the aging program for the steam dryer (including required qualifications of the individuals performing these assessments)" is adequate; and 2) whether Entergy's program "need[s] to involve some form of stress load analysis as part of this program to help assure protection of public safety during the license renewal period." *Id.* at 13-14.[31]

B. Witnesses

151. During the hearing two witnesses testified on behalf of Entergy, one testified for NEC, and three testified for the Staff. Direct testimony was submitted by Entergy, NEC, and the Staff.[32] Rebuttal testimony was also filed by NEC's witness.[33] All six witnesses provided oral testimony in response to questions posed by the Board.

152. Entergy presented the testimony and opinions of two qualified witnesses: 1) Mr. John R. Hoffman and 2) Mr. Larry D. Lukens. Mr. Hoffman is a former Entergy Engineering Projects Manager who retired from Vermont Yankee in 2006. Exh. E3-02. He

---

[31] As discussed above, *see supra* Sect. II.A.2, the Board granted Entergy's summary disposition order with respect to NEC's allegation that Entergy's steam dryer AMP was inadequate "because of alleged inadequacies in the computational fluid dynamics ("CFD") and acoustic circuit model ("ACM") computer models, and because Entergy will not be conducting continuous monitoring of the steam dryer during the license renewal period." NEC 3 SD Order at 10.

[32] Joint Declaration of John R. Hoffman and Larry D. Lukens on NEC Contention 3 – Steam Dryer, Post Tr. 1187 ("Entergy Direct Testimony NEC Contention 3"); Direct Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3, and 4, Post Tr. 779 ("Hopenfeld Decl."); Affidavit of Kaihwa R. Hsu, Jonathan G. Rowley, and Thomas G. Scarbrough Concerning NEC Contention 3 (Steam Dryer), Post Tr. 1190 ("Staff Direct Testimony NEC Contention 3").

[33] Pre-filed Rebuttal Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3, and 4, Post Tr. 779 ("Hopenfeld Rebuttal").

holds a BE degree in mechanical engineering, MS degree in nuclear engineering, MS degree in applied management, and has over thirty-seven (37) years of experience in nuclear plant engineering. *See id.* Mr. Hoffman has directed engineers for the Yankee, Maine Yankee, Vermont Yankee, and Seabrook Nuclear Power Stations. *Id.* At Vermont Yankee, Mr. Hoffman's team was responsible for the development of Vermont Yankee's proposed steam dryer aging management program and he was personally responsible for ensuring that the steam dryer aging management program was properly developed and reviewed. Entergy Direct Testimony NEC Contention, Post Tr. 1187, at A5.

153. Mr. Lukens is a former Entergy Supervisor of Code Programs, Senior Lead Engineer in System Engineering, Code Programs, and IST Coordinator. Exh. E3-03. He holds a BS degree in nuclear engineering, attended the US Navy Nuclear Power School, and has been certified as a Senior Reactor Operator, a U.S. NRC Licensed Reactor Operator, and a US Navy Nuclear Qualified Reactor Operator. *Id.* Mr. Lukens has over forty years of experience in the nuclear industry. *Id.* While at Vermont Yankee, Mr. Lukens was responsible for ensuring all industry code required activities, particularly the ASME code requirements, were completed, evaluated, dispositioned, and documented. Entergy Direct Testimony NEC Contention, Post Tr. 1187, at A7. Mr. Lukens was directly involved with license renewal audits and inspections of Code programs activities, and he approved the license renewal commitments related to these programs. *Id.*

154. NEC presented one witness, Dr. Joram Hopenfeld, a professional consultant and CEO of Noverflo, Inc. Exh. NEC-JH_02. Dr. Hopenfeld holds BS, MS, and PhD degrees in engineering, and has 45 years of experience in the areas of thermal hydraulics, materials, corrosion, radioactivity transportation, instrumentation, PWR steam generator testing and accident analysis. *Id*. For nearly twenty years Dr. Hopenfeld was employed by the NRC, during

which time he worked on matters related to PWR steam generators. Prior to working for the NRC, Dr. Hopenfeld worked for the Department of Energy, also on matters related to steam generators. *Id.*

155. The Staff presented the testimony and opinions of three qualified witnesses: 1) Mr. Thomas G. Scarbrough, 2) Mr. Jonathan G. Rowley, and 3) Mr. Kaihwa R. Hsu. Mr. Scarbrough is employed by the NRC as a Senior Mechanical Engineer in the Division of Engineering, Office of New Reactors. *See* Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at Statement of Professional Qualifications of Thomas G. Scarbrough. He holds a Bachelor of Arts ("BA") degree in physics, Bachelor of Nuclear Engineering ("BNE") degree in nuclear engineering, and MS degree in mechanical engineering. *Id.* He is also a registered Professional Engineer and a member of the American Nuclear Society. *Id.* Mr. Scarbrough has over thirty years of technical experience in the nuclear field, during which time he has participated in the review of a number of power uprate requests, including Vermont Yankee. *Id.*

156. Mr. Rowley is employed by the NRC as a Project Manager in the Office of Nuclear Reactor Regulation, Division of License Renewal. *Id.* at Statement of Professional Qualifications of Jonathan G. Rowley. He is the lead project manager for the Staff's safety review of the Vermont Yankee LRA. *Id.* at A2(b). As the lead project manager, Mr. Rowley was responsible for coordinating the Staff's evaluation of the Vermont Yankee LRA and the Staff's Safety Evaluation Report. *Id.* Mr. Rowley holds BS and MS degrees in materials science and engineering. *Id.* at Statement of Professional Qualifications of Jonathan G. Rowley. Mr. Rowley has over 14 years of experience in materials science and engineering and over five years of experience in nuclear regulation. *Id.*

157. Mr. Hsu is employed by the NRC as a Senior Mechanical Engineer in the Division of Engineering, Office of New Reactors (former Materials Engineer in the Office of

Nuclear Reactor Regulation, Division of License Renewal). *Id.* at Statement of Professional Qualifications of Kaihwa R. Hsu. Mr. Hsu was part of the Audit team for the license renewal safety audit at Vermont Yankee and he served as a technical lead. *Id.* at A4(a). Mr. Hsu holds BS and MS degrees in civil engineering. *Id.* Prior to joining the NRC in 2003, Mr. Hsu was a principal engineer at Westinghouse. *Id.*

158. All witnesses were found to be qualified to present testimony on the areas they addressed. The Board has accorded each witness's testimony the weight appropriate to his level of knowledge, training and experience related to the subject matter of the contention.

C. Steam Dryer Background

159. The steam dryer is a non-safety related, non-Seismic Category I component located above the steam separator assembly in the reactor head. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A11 p.5; Exh. NEC-JH_54 at 1 ("The steam dryer has no safety functions.").

160. In 2004, in preparation for the EPU, Vermont Yankee made a number of physical modifications to fortify its steam dryer. Tr. 1416, 1419 (Lukens). These modifications included replacing the vertical sections of the hood, reinforcing the welds in that vertical section, replacing the end plates, and replacing tie bars. Tr. 1417-18 (Lukens); Exh. E3-04 at 10-12 (describing dryer modifications). All replacements were done with a more robust material than what had previously been installed. Tr. 1417 (Lukens).

161. As a non-safety related component, the steam-dryer "is not required to prevent or mitigate the consequences of accidents." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A13 p.6. The assembly is, however, "designed to withstand design basis events without the generation of loose parts and the dryer is designed to maintain its structural integrity through all the plant operating conditions." Exh. NEC-JH_61 at 2, ¶7 ("Declaration of John R.

Hoffman in Support of Entergy's Motion for Summary Disposition of NEC Contention 3 (Apr. 18, 2007)). The concern with regard to the condition of the steam dryer is that it "must maintain its structural integrity to avoid loose dryer parts from entering the reactor vessel or steam lines and adversely affecting plant operation." Exh. NEC-JH_56 at 3 (NRC Information Notice 2002-26, Supplement 2).

162. Failure is defined as "[a] loss of physical integrity of the dryer such that loose dryer sections or parts are released to the reactor steam space (that is, the space in the reactor where steam is confined above the water) and potentially migrate to other components." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A14 p.6. The formation of cracks does not constitute failure. *See id.* at A15.

D. Steam Dryer Aging Management Program

163. In the Vermont Yankee LRA, Entergy addresses aging management of the steam dryer as follows:

> [c]racking due to flow-induced vibration in the stainless steel steam dryer is managed by the BWR Vessel Internals Program. The BWR Vessel Internals Program currently incorporates the guidance of GE-SIL-644, Revision 1. VYNPS will evaluate BWRVIP-139 once it is approved by the staff and either include its recommendations in the VYNPS BWR Vessel Internals Program or inform the staff of VYNPS's exceptions to that document.[34]

Entergy Direct Testimony NEC Contention 3, Post Tr.1187, at A21 p.10 (Hoffman) (quoting

---

[34] The admitted contentions do not specifically challenge the adequacy of the BWRVIP-139 program. *See* LBP-06-20, 64 NRC at 187; NEC 3 SD Order; Petition for Leave to Intervene, Request for Hearing and Contentions (May 26, 2006), Exh. 7 (Declaration of Dr. Joram Hopenfeld) at ¶18 (stating that "[n]o matter which guidance Entergy follows, the status of the existing dryer cracks must be continuously monitored and assessed by a competent engineer.")). The Board is not permitted to raise issues *sua sponte* unless it is a serious safety or environmental issue *and* Commission permission to consider the issue has been granted. *See* 10 C.F.R. § 2.340(a).

License Renewal Application § 3.1.2.2.11).

164. The Staff, during the license renewal audit and review of Entergy's LRA, noted that the BWR Vessel Internals Program did "not address steam dryer in the AMP" and asked that the applicant provide additional information regarding the steam dryer AMP. *See* Staff Exh. 1 at 3-56, 3-174 to 3-175. Vermont Yankee's technical personnel replied that the steam dryer monitoring plan ("SDMP") had already been submitted and approved by the staff as part of the power uprate application. Staff Exh. 1 at 3-174. Specifically, the EPU license condition required Entergy to "revise the SDMP to reflect long-term[35] monitoring of plant parameters potentially indicative of steam dryer failure" and "to reflect consistency of the facility's steam dryer inspection program with General Electric Services Information Letter 644, Revision 1 . . . ." Staff Exh. 14 at Amendment 229, p. 4, ¶e; Tr. 1196-97 (Scarbrough); Joint Stipulations at ¶¶13,15 (July 8, 2008).

165. The Staff, with technical assistance from Argonne and its subcontractors, reviewed Entergy's SDMP as part of the EPU license amendment request for Vermont Yankee. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A5(a) p.6. The Staff found that Entergy's SDMP "provided reasonable assurance that the flow-induced effects on the steam dryer were within the structural limits at then – CLTP [Current Licensed Thermal Power] conditions . . . [and] that Entergy had demonstrated that the steam dryer would continue to meet NRC regulatory requirements "following implementation of the EPU at Vermont Yankee, subject

[35] In contrast, other EPU license conditions regarding steam dryer inspections are not required to be implemented on a long-term basis and therefore will terminate prior to the period of extended operation. *See e.g.,* Staff Exh. 14 at 11, ¶8 (stating that the license condition will expire when the requirements in paragraphs 5, 6, and 7 are satisfied, "provided that visual inspection of the steam dryer does not reveal any new unacceptable flaws or unacceptable growth that is due to fatigue."); Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A4(b) pp. 4-5.

to the license conditions specified in the EPU license amendment." *Id.* at A6(a) p.8. In March 2006, Entergy was granted an Extended Power Uprate License. Tr. 1411 (Scarbrough). This license allowed Vermont Yankee to increase its power level twenty percent, from 1593 megawatts thermal ("MWt") to 1912 MWt. NEC-JH_61 at 2, ¶8.

166. During the evidentiary hearing, the Staff and Entergy testified that the recommendations of GE-SIL-644 are part of Entergy's CLB as a result of the EPU license condition. Tr. 1412 (Rowley, Lukens). Furthermore, the Staff and Entergy testified that the CLB carries forward into the renewal period. *See* Tr. 1229 (Lukens responding to J. Wardwell); Tr. 1230 (Rowley); *see also* 10 C.F.R. § 54.33(d). Entergy testified that if Vermont Yankee's license is renewed, Vermont Yankee will continue inspections and monitoring in accordance with the GE-SIL-644 during the period of extended operation. Tr. 1208 (Lukens). SDMP incorporates the recommendations of GE-SIL-644. Staff Exh. 14; Tr. 1196-97 (Scarbrough). Thus, Entergy's proposal to use SDMP, Revision 3 to manage aging effects on the steam dryer is simply a continuation of its current program which will carry forward into the period of extended operation. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A4(c); Tr. 1196 (Scarbrough).

167. The proposed Steam Dryer AMP is designed to manage cracking due to flow-induced vibration in the steam dryer by inspecting and monitoring for issues that may indicate failure. *See* Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A21 p.10. Entergy's witnesses, Mr. Hoffman and Mr. Lukens, stated that Vermont Yankee's proposed monitoring and inspection programs for the steam dryer conform to the recommendations in GE-SIL-644. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A22 p.11. Moreover, Entergy's long-term program "uses the latest approved examination techniques and is consistent with the current industry best practice." *Id.* at A55 p.29.

168. The Staff reviewed Entergy's LRA application and conducted a license renewal safety audit. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A2(a) p.2. Based on its review, the Staff found that there is reasonable assurance that the steam dryer will perform safely during the proposed renewal period if the plant uses an adequate aging management program. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A6(b); Staff Exh. 1 at 3.3.1.2.2.11. The Staff found the BWR Vessel Internals Program and SDMP, Revision 3, to be adequate methods for managing aging of the steam dryer. *Id*. Specifically, the Staff found the SDMP to be acceptable because it incorporates the recommendations of GE-SIL-644, which will include updated industry operating experience and technology. *Id.*

169. In addition, consistent with Staff guidance (Staff Exh. 19 NUREG-1800, "Standard Review Plan for License Renewal Application of Nuclear Power Plant" Rev. 1 (Sept. 2005)),[36] SER Commitment 51 states that "Entergy will perform an evaluation of operating experience at EPU levels prior to the period of extended operation to ensure that operating experience at EPU levels is properly addressed by the aging management programs." Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A6(b); *see also* Staff Exh. 1 at A-16. The evaluation will consider operating experience at Vermont Yankee and at other BWR plants operating at EPU levels. Staff Exh. 1 at A-16.

170. The SDMP has two parts: a long-term monitoring program and a long-term inspection program. Tr. 1359 (Lukens). Each part will be addressed in turn below.

---

[36] NUREG-1800 states that all license renewal applications with approved EPUs should commit to performing an operating experience review assessing the impact of the EPU on aging management programs for structures, systems, and components prior to the period of extended operation. Staff Exh. 19 at 3.0-4.

1. Monitoring Program

a. Monitoring Program Procedures

171. In accordance with the SDMP, Entergy's plant operators and technical staff continuously monitor the status of the steam dryer. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A24. Specifically, the program monitors for the following events which "could be indicative of significant dryer damage: (a) sudden drop in main steam line flow >5%; (b) .3 inch difference in reactor vessel water level instruments; and (c) sudden drop in steam dome pressure >2 psig. In addition, "periodic [once a week] measurements of moisture carryover are performed" and are evaluated in accordance with GE-SIL-644. *Id.*; Tr. 1305-07 (Hoffman).

172. If the above changes are noticed in the monitored parameters, then Entergy's procedures require that a moisture-carryover measurement be taken. Tr. 1309 (Hoffman). Mr. Hoffman testified that if the moisture carryover measurement is above normal, then Vermont Yankee Off-Normal Procedure ON-3178 (Exh. E3-07) is implemented. Tr. 1309 (Hoffman).

173. Moisture carryover is measured in accordance with Entergy procedure OP-0631 Appendix F (Exh. E3-10). Entergy Direct Testimony NEC Contention 3, Post Tr. 1187 at p.12, A27. This procedure specifies that if moisture carryover is >.16% and < .35% then a Condition Report ("CR") must be written, a number of plant personnel notified, and actions in ON-3178 (Exh. E3-07)[37] followed. Exh. E3-10; Tr. 1309 (Hoffman). Mr. Hoffman testified that if changes in monitored parameters are observed, then work will begin immediately, by a number of

[37] ON-3178 provides that if there is an indication in the monitoring parameters of damage or debris, then a moisture carryover sample and analysis must be conducted. Exh. E3-07 at 2.

people, to determine the cause for the change in plant parameters. Tr. 1271, 1309-10 (Hoffman). If the moisture carryover evaluation does not support continued plant operation, the plant will be shutdown. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A28 p.13.

b. Personnel Qualifications

i. Evidence

174. NEC Contention 3, as amended by the Board, alleges that Entergy's program is inadequate because Entergy has not provided information regarding the qualifications of personnel evaluating Vermont Yankee's monitoring data. NEC 3 SD Order at 12.

175. NEC did not, however, offer testimony or exhibits to indicate that persons reviewing Entergy's monitoring data were not qualified. *See* New England Coalition, Inc Initial Statement of Position (Apr. 28, 2008) at 20 (identifying the three issues, as narrowed by NEC 3 SD Order, regarding contention 3 and stating that NEC's direct testimony and exhibits address the third of these issues – "whether the aging management plan should include stress analysis for comparison to fatigue limits as a component of the plan").

176. To the contrary, Entergy witness Mr. Hoffman testified that all engineers who do independent work are in fact qualified through the Institute of Nuclear Power Operations (INPO) Engineering Support Personnel (ESP) training program. Tr. 1395 (Hoffman). In addition, supervisors verify that engineers have properly completed training, have performed work under the guidance of someone else, and that supervisors are satisfied with the engineer's work. Tr. 1395-96 (Hoffman). Furthermore, all persons involved in assessing the moisture carryover and monitoring procedures are qualified in Entergy's operability determination procedures, EN-OP-0104 (Exh. E3-11). Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A31 p.14. Finally, Mr. Hoffman testified that Entergy "takes it very seriously that unqualified

personnel do not perform safety-related work. People need to meet the qualifications to do the work." Tr. 1396 (Hoffman).

177. Mr. Hsu and Mr. Rowley stated that Entergy's qualification program is a current operating issue. Tr. 1398-99 (Rowley, J. Wardwell). Based on NRC staff review of the EPU application and interactions during EPU power ascension, Mr. Scarbrough testified that Entergy's personnel were capable of analyzing plant data related to steam dryer performance. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A12 p.11.

ii. Board Findings

178. The Board finds that Entergy has provided sufficient information to demonstrate that Vermont Yankee personnel reviewing monitoring data are qualified. Furthermore, the Board finds that NEC failed to offer evidence to indicate otherwise. This part of Contention 3 is resolved in favor of Entergy.

2. Inspection Program

179. The inspection aspect of Entergy's SDMP, Revision 3 is performed in accordance with VY BWRVIP Program Plan (Exh. E3-12) and GE-SIL-644, Revision 1 (Exh. E3-06). Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A35 p.16; Joint Stipulations at ¶¶14, 15 (July 8, 2008).

180. Entergy's program states that the dryer is currently inspected each scheduled refueling outage, which is every eighteen months (Tr.1282 (Lukens)), with VT-1 and VT-3 visual inspections.[38] Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A35 p.16. The

[38] The VT-1 inspections are capable of achieving a resolution to discern 0.044 inch, Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A36, "which is slightly larger than the micro-engraving on a dollar bill." *See* Tr. 1365 (Lukens). Alternatively VT-3 inspections only require (continued. . .)

personnel who perform these examinations are qualified in accordance with the ASME Boiler and Pressure Vessel Code Section XI. *Id*. (Lukens).

181. Areas inspected during VT-1 and -3 exams include "all accessible internal and external welds and plates in the steam dryer that are potentially susceptible to crack formation." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A35 p.16. *See also* Tr. 1373-74 (Lukens) ("The fundamental scope [of inspections] using SIL-644 is all the accessible susceptible areas."). Steam dryer inspections are performed using high resolution color cameras, the results of which are recorded on a DVD which allows for future review. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A36 p.17.

182. An indication is an "imperfection or unintentional discontinuity that is detected by nondestructive examination" and is classified as recordable or relevant if it is visible during the exam. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A43 p.20. Mr. Lukens testified that all detected indications are recorded (Tr.1368 (Lukens)) and evaluated by qualified engineers to determine whether they are potential cracks or surface imperfections. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A42 p. 20.

183. There are three types of cracks which may be identified during an inspection: 1) fatigue cracks; 2) intergranular stress corrosion cracks ("IGSCC"); and 3) stress relief cracks. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A44 p.21.

184. If an indication is examined and the potential of a fatigue crack cannot be ruled out, then the indication is identified as potential fatigue and will be examined in subsequent

---

(. . .continued)

recognition of 0.105 inch. *Id.* at A36 p.17.

examinations to ensure that there is no growth. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A44 p. 21. GE-SIL-644 requires that "flaws left 'as-is' should be inspected during each scheduled refueling outage until it has been demonstrated that there is no further crack growth and the flaws have stabilized." Exh. E3-09 at p.6, A.1.c. Mr. Lukens testified that there is no further crack growth degradation if a "crack is shown not to be growing in the two inspections following its initial discovery. . . ." Tr. 1371 (Lukens).

185. Mr. Lukens testified that Entergy has performed VT-1 examinations on its steam dryer during the 2004,[39] 2005,[40] and 2007[41] refueling outages. Tr. 1360-67 (Lukens); Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A46 pp.22-25.[42] Mr. Lukens testified further that during these inspections, all the recorded cracks were identified as IGSCC cracks, the growth rate of which is 5×10^{-5} inches per hour, which roughly translates into about half an inch per year. Tr. 1361 (Lukens).[43] In addition, the inspections have shown that "[n]one of the previously identified indications showed growth, which suggests that fatigue is not occurring."

---

[39] Twenty indications were identified, two of which needed repairs. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A46; Tr. 1360 (Lukens). All the cracks found during this inspection were identified as IGSCC. Tr. 1362 (Lukens).

[40] The 2005 VT-1 examination was superior in quality to the 2004 VT-1 examination, meaning there was better resolution. Tr. 1364 (Lukens). During this examination, all the 2004 indications were identified, none of which had grown. Tr. 1366 (Lukens).

[41] The 2007 examination identified forty-eight previously identified indications, none of which had grown and twenty-eight new indications, all of which were classified as IGSCC. Tr. 1367 (Lukens). Finally, nine previously identified indications from 2005 were determined to be non-relevant indications. *Id.*

[42] Mr. Lukens testified that the vessel head must be removed in order to inspect the steam dryer. Tr. 1419-20 (Lukens). Therefore, it is not practical to inspect the steam dryer other than during refueling outages. Tr. 1420 (Lukens answer to J. Reed's question).

[43] Even NEC acknowledges that GE found that all cracks identified during Vermont Yankee's Refueling outage ("RFO") 26 were IGSCC. NEC-JH_54 at 3.

Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A49 p.27 (Lukens).

E. Factual Findings on Key Contested Issues

186. NEC contends that Entergy's steam dryer aging management program is inadequate because it "consists solely of plant parameter monitoring and partial visual inspection, uninformed by knowledge of dryer loading." Hopenfeld Rebuttal Testimony, Post. Tr. 779, at A28 p.20. To be adequate, NEC states that Vermont Yankee's steam dryer AMP should have a means to estimate and predict stress loads, establish dryer flow induced vibration load fatigue margins and demonstrate that stress on the dryer does not exceed ASME endurance limits. Exh. NEC-JH-54 at 5. In addition, Dr. Hopenfeld suggests that operation of the dryer using Entergy's proposed program "is a direct threat to public health and safety." Exh. NEC-JH_54 at 6.

1. Program's Ability to Predict Stress Loads

a. Evidence

187. NEC contends that Entergy's monitoring program, to be sufficient, must include a means of *predicting* and estimating stress loads. Exh. NEC-JH-54 at 5. Dr. Hopenfeld states that "moisture monitoring only indicates that failure has occurred. It does not prevent the failure from occurring." Hopenfeld Decl., Post Tr. 779, at A53; Tr. 1401 (J. Reed summarizing Dr. Hopenfeld's position). However, Dr. Hopenfeld admits that "no one can predict the exact time for transition from crack initiation to crack propagation." Hopenfeld Rebuttal Testimony, Post Tr. 779, at A28 p.20. Furthermore, Dr. Hopenfeld postulated that Entergy's monitoring program will only indicate the formation of cracks that increase moisture carryover but cannot indicate the formation of cracks that do not increase moisture carryover. Exh. NEC-JH_54 at 5.

188. Entergy's program is not, however, designed to predict whether a dryer crack is about to form. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A33 p.15.

Rather, as Mr. Hoffman testified, the monitoring program is designed to provide early warning that a crack may have developed. Tr. 1314 (Hoffman); Tr. 1402 ("Monitoring of plant parameters will not predict the incipient formation of cracks, but it will identify the existence of cracks sufficiently large to adversely affect dryer performance and flag the risk of structural failure of the dryer." (J. Reed question stating Hoffman's position)). *See also* Tr. 1321 (Hsu) (stating that the monitoring program can't predict that a crack may develop but will determine if degradation that challenges steam dryer integrity has occurred).

189. Entergy's SDMP is "based on the principle that that periodic monitoring and inspection, informed by knowledge of plant materials and the physics of stress, strain, flaw initiation and crack propagation, will monitor material conditions on a frequency that is sufficient to identify and mitigate any flaws before they can grow to a size that would be detrimental to the integrity of the component under consideration." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A55 pp.29-30. Mr. Hoffman testified that Entergy's monitoring program will indicate if there is a problem in the steam dryer and there will be a sufficiently long time to analyze the monitoring data, perform necessary evaluations, and shut the plant down if necessary. Tr. 1404 (Hoffman).

190. Moreover, GE-SIL-644 states that while monitoring of the steam dryer does not consistently predict cracks, it "is still useful in that it does allow identification of a degraded dryer allowing appropriate action to be taken to minimize the damage to the dryer and the potential for loose parts generation." Exh. E3-09 at 6. The monitoring parameters will indicate that steam leaving the reactor has high moisture content, which may indicate that dryer degradation has occurred. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A25 (Hoffman) (citing Exh. E3-06, Appx. D).

191. Mr. Hoffman explained that the dryer is a part of the steam flow path and that

unexplained changes in the steam flow rate, reactor vessel water level and/or dome pressure can indicate a change in steam path pressure, which in turn indicates a loss of dryer efficiency. Entergy Direct Testimony, Post Tr. 1187, at A54. A loss of efficiency may be an indication of steam dryer damage. *Id.* Mr. Hoffman further testified that for a crack to challenge dryer integrity it would have to develop through the dryer wall. Tr. 1298-99 (Hoffman). This would allow steam flow to leak out through the crack, Tr. 1299 (Hoffman), and that the monitoring program is designed to detect such a breach or bypass, Tr. 1302 (Hoffman response to J. Wardwell). Mr. Hoffman testified further that the program is capable of identifying "a crack sufficiently large to adversely affect dryer performance and flag the risk of structural failure of the dryer." Entergy Direct Testimony, Post Tr. 1187, at A53.

192. Nonetheless, NEC contended that Entergy's SDMP should include a means of estimating and predicting stress loads on the dryer. NEC-JH-53 at p.9, A16. Dr. Hopenfeld reasons that "[t]he ability to estimate the probability of formation of loose parts requires knowledge of the cyclic loads on the dryer to ensure that the dryer is not subjected to cyclic stress that would exceed the endurance limit." Hopenfeld Rebuttal Testimony, Post Tr. 779, at A28 p.21. Dr. Hopenfeld contended that measuring stresses using strain gauges on the main steam lines and not the dryer itself, which Entergy did during power ascension, is not sufficient. Tr. 1287-88 (Hopenfeld). Entergy had installed strain gauges on the main steam lines in order to take confirmatory measurements for their stress analyses during power ascension. Tr. 1286 (Hoffman); Exh. NEC-JH_61 at ¶13. The gauges monitored the pressure fluctuations within the main steam flow. Exh. NEC-JH_54 at 2. The gauges have since been removed, (Tr. 1286 (Hoffman)), which Dr. Hopenfeld states, was a mistake, NEC-JH_54 at 6.

193. Entergy witness, Mr. Lukens, testified that Dr. Hopenfeld's suggestion to measure stress directly on the dryer is not feasible because attaching strain gauges directly to

the dryer would require welding, which in turn would create new high-stress areas. Tr. 1380-81 (Lukens). In addition, placement of strain gauges directly on the dryer would involve additional wires in the reactor vessel. *Id.* Such "paraphernalia becomes potentially loose parts." Tr. 1381 (Lukens).

194. Dr. Hopenfeld conceded "that there is no regulatory requirement to estimate dryer stresses." Hopenfeld Rebuttal, Post Tr. 779, at A29 p.21. *See also* Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A60 p.32 (stating "there is no regulatory requirement or industry guidance that calls for ongoing estimation of stream dryer stresses"). Moreover, the Staff found that Entergy demonstrated pressure loads during EPU operation would not result in stresses above the ASME fatigue limits and that continued stress analysis was unnecessary. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A15 pp.12-13.

b. Board Findings

195. The Board finds that Entergy's program, which is designed to provide early warning of potential dryer degradation, is adequate. Entergy has demonstrated that this program will provide sufficient warning, allowing Entergy ample time to analyze the situation and take necessary actions to minimize any damage and the potential generation of loose parts. The Board finds persuasive Entergy's testimony that it is not viable or feasible to measure stress *directly* on the steam dryer. NEC has failed to provide any evidence to suggest that additional and practical techniques for monitoring stress directly on the steam dryer are available and should be included in Entergy's monitoring program. Furthermore, the Board finds that there is no regulatory requirement for Entergy to monitor stress via strain gauges. Thus, the Board finds that the monitoring aspect of Entergy's SDMP for the period of extended operation provides reasonable assurance that the effects of aging will be adequately managed.

2. Fatigue Limits

a. Evidence

196. In recent years, industry experience, specifically the events at Quad Cities caused by flow-induced vibration resulting in metal fatigue failure, has raised concern regarding the need to assure steam dryer physical integrity. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A12 p.6; Exhs. E3-06 & E3-09 (discussing the Quad Cities events); *see also* Joint Stipulations at ¶¶8-9 (July 8, 2008).[44]

197. As a result of the Quad Cities incidents, Vermont Yankee instituted a dryer monitoring and inspection program to "provide assurance that that flow-induced loadings under normal operation at EPU levels did not result in the formation or propagation of cracks." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A16. As stated above in Section D, this program was reviewed and approved by the Staff as part of the EPU license review. *Id.*

198. In addition, Entergy has determined, through design analyses, "that there would not be a high-cycle fatigue problem [at Vermont Yankee] which would lead to the generation of loose parts. The startup test – or the power ascension test program for the power uprate confirmed the validity of those analyses and there is nothing that could cause those stresses to change . . . ." Tr. 1282-83 (Hoffman). Mr. Hoffman testified that analyses were performed and confirmatory measurements were taken during the power ascension test program to validate these computations. Tr. 1285 (Hoffman). The confirmatory measurements used to validate

---

[44] Prior to recent modifications to improve the structural capability of the Vermont Yankee steam dryer, Entergy's witness Mr. Hoffman testified that the original Quad Cities BWR steam dryer was similar to Vermont Yankee's BWR steam dryer. *See* Tr. 1261 (Hoffman).

fatigue analyses were taken by strain and pressure gauges placed on the main stream lines. Tr. 1285-86 (Hoffman).

199. In addition, Mr. Hoffman testified that the fact that Vermont Yankee has operated at the uprated level for approximately two years and has not yet had failure, strongly suggests that Vermont Yankee's steam dryer will not experience a fatigue-induced failure. *See* Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A62 p.33.

200. Dr. Hopenfeld disagreed with Entergy, testifying that the possibility of high-cycle fatigue cracking at Vermont Yankee cannot be ruled out. Tr. 1325-26 (Hopenfeld response to J. Reed question). Dr. Hopenfeld contended that the "fact that cracks have not developed after a short period of time proves nothing." Hopenfeld Rebuttal Testimony, Post Tr. 779, at A29 p.21. Dr. Hopenfeld reasoned that if cracking due to flow-induced vibration was ruled out based on the fact that it has not yet happened, then we would never see cracking due to flow-induced vibration in a dryer beyond eighteen (18) months of operation. Tr. 1326-27 (Hopenfeld). Dr. Hopenfeld could not, however, provide any example of a dryer that failed as a result of flow-induced vibration after more than eighteen (18) months of operation. Tr. 1327-28 (Hopenfeld).

201. Mr. Scarbrough testified that he was unaware of any dryers that had significant failure due to high-cycle fatigue cracking after 18 months of operation. *See* Tr.1328-30; Tr. 1330 (Scarbrough). In particular, he stated that the Quad Cities Unit 2 steam dryer had failed with loose parts after about 90 days of initial EPU operation and that the Quad Cities Unit 1 steam dryer failed with loose parts after about one year of EPU operation. Tr. 1328 (Scarbrough). Mr. Scarbrough further testified that the Dresden Units 2 and 3 steam dryers developed less significant cracks over about an eighteen month time period during initial EPU operation. Tr. 1329-30 (Scarbrough).

202. Dr. Hopenfeld further contended that the fact that the dryer has not yet failed "is not at all an indication that it will not fail in the future." Hopenfeld Rebuttal Testimony, Post Tr. 779, at A33 p.23. Dr. Hopenfeld could not, however, provide an answer as to the time period for which an observation of no cracks would indicate that the endurance limit would not be exceeded under normal power uprate conditions. Tr. 1385 (Dr. Hopenfeld could not answer J. Reed's question).

203. Staff witness, Mr. Scarbrough, testified that based on industry operating experience, three consecutive inspections with no indications of fatigue cracking is sufficient to conclude that stress loads are below the endurance limit, and therefore cracks associated with vibration fatigue are not expected to occur under normal power uprate conditions at those loads. Tr. 1386 (Scarbrough).

204. Finally, Dr. Hopenfeld contended that fatigue cracking at Vermont Yankee could not be ruled out based on Vermont Yankee's inspection results. Tr. 1384 (Hopenfeld response to J. Reed's questions). In support of this position, Dr. Hopenfeld points to Entergy's draft report of its 2007 refueling outage which itself states that "fatigue cracking at these locations of IGSCC cannot be ruled out." NEC-JH_68 (CR-VTY 2007-02133); NEC Pre-Filed Rebuttal Testimony, Post Tr. 779, at A29 p.21-22.

205. Entergy's witness Mr. Lukens testified that the statement Dr. Hopenfeld relied on was in a draft report (Tr. 1377-78 (Lukens)), and was never included in Entergy's signed report, (Tr. 1378-79 (Lukens)). In addition, Mr. Lukens stated that this "phrase added no engineering or technical value to the conclusions in that report." *Id.* at 1379 (Lukens). This "sentence lended an air of ambiguity that the engineering evaluation did not support." Tr. 1379 (Lukens). Most importantly, Mr. Lukens testified that the statement Dr. Hopenfeld relied on raised an irrelevant issue because Entergy has determined that IGSCCs are not in locations susceptible to fatigue

cracking. Tr. 1379 (Lukens response to J. Wardwell).

206. Moreover, Vermont Yankee has "never found an indication in a high-stress area of the dryer." IGSCC cracks have all been in low-stress areas. Tr. 1376 (Lukens). In order for an IGSCC crack to grow into a fatigue crack, the IGSCC crack must be in a location where there is a "cyclic stress above the endurance limit." Tr. 1420 (Lukens). Furthermore, based on Entergy's inspection results, Entergy found that growth was not occurring in previously identified indications and none of the previous indications were determined to be associated with fatigue. Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A49.

207. Moreover, the Staff testified that it had reviewed the 2007 refueling outage evaluation and did not find anything significant that would raise concern. Tr. 1387-88 (Scarbrough). Mr. Scarbrough stated that based on the Staff's review of the inspection results, the Staff found that there were no significant issues. *Id.* (Scarbrough).

b. Board Findings

208. The Board finds that the steam dryer at Vermont Yankee is not subject to high-cycle fatigue failure. The Board agrees that if the dryer were subject to high-cycle fatigue failure, it would have already occurred. NEC did not provide evidence to suggest otherwise.

209. The Board also finds that the inspection results clearly indicate that no fatigue cracks have been found at Vermont Yankee, only IGSCC have been identified. The inspection data indicate that none of the identified IGSCC have grown. Furthermore, the Board finds that the frequency of steam dryer inspections under this program is adequate.

210. Finally, the Board finds that NEC's reliance on an Entergy draft report to support the proposition that fatigue cracking is occurring at locations of IGSCC is unpersuasive. The Board finds Entergy's explanation of this draft report reasonable and the Staff's review supports Entergy's explanation.

3. Crack Propagation

a. Evidence

211. NEC contended that if a fatigue crack initiates, it will propagate very quickly when exposed to "alternating stresses of sufficient magnitude and frequency." Exh. NEC-JH_54 at 4. To support this proposition, Dr. Hopenfeld relied on a statement in the Pacific Northwest National Laboratory report: "vibration fatigue does not lend itself to periodic in-service examination because once a crack initiates, failure quickly follows." Exh. NEC-JH_63 at 24.

212. Entergy rebutted this assertion by showing first that Dr. Hopenfeld has taken this sentence out of context. Tr. 1392-94 (Lukens). This section refers to "socket welded vent and drain connections less than one inch thick in power plants and has *nothing* to do with steam dryers in boiling water reactors." Tr. 1393-94 (Lukens) (emphasis added).

213. Second, Entergy's inspection results indicate that if there was a flaw developing, it would develop very slowly. Tr. 1303 (Hoffman). Moreover, Mr. Hoffman explained that the steam dryer is made of stainless steel, which is a very ductile material, unlike a material such as glass which is brittle, so cracks will propagate very slowly. Tr. 1304 (Hoffman).

214. Third, Entergy noted that "Dr. Hopenfeld's concern is based on the assumption that there will be alternating stresses of sufficient magnitude and frequency to cause cracks to propagate rapidly." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A56 p.30. To the contrary, Vermont Yankee's operating experience since EPU shows that the dryer stresses are not sufficient enough to "initiate and propagate fatigue cracks." *Id.* Entergy and the Staff monitored plant parameters during Vermont Yankee's EPU power ascension to confirm that pressure loads on the steam dryer resulted in stresses that remained below the fatigue stress limits in the ASME Boiler & Pressure Vessel Code. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A5(a). The Staff found reasonable assurance that the stress on

the dryer during EPU conditions would remain below the fatigue stress limits specified in the ASME Code. Tr. 1409-10 (Scarbrough).

215. Accordingly, the Staff found that Entergy demonstrated that the pressure loads during EPU operation do not result in stress on the steam dryer exceeding the ASME fatigue stress limits and therefore Entergy's AMP does not need to include flow-induced vibration fatigue margins. Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A15 p.13.

216. Finally, Entergy testified that "there will be no change in dryer loads or stress during the license renewal period of operation; hence there is no reason to expect that the dryer will be subjected to increased stresses in the future." Entergy Direct Testimony NEC Contention 3, Post Tr. 1187, at A61 p.32. The Staff agreed. *See* Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at A14 pp.12-13.

b. Board Findings

217. The Board finds Entergy has demonstrated that if a crack were to develop in Vermont Yankee's steam dryer, it would not propagate quickly because, as indicated above, Vermont Yankee's steam dryer is not subject to high-cycle fatigue failure. Rather, the Board finds that the stress on the stream dryer is and will continue to be below the ASME Code endurance limit. The Board finds NEC's reliance on the Pacific Northwest Laboratory Report unpersuasive.

4. Public Safety Hazard

a. Evidence

218. Dr. Hopenfeld contends that a public safety hazard would result if the dryer were damaged and loose parts were transported to other areas of the reactor system. Tr. 1244 (Hopenfeld response to J. Reed's question); Exh. NEC-JH_54 at 1. To support his position, Dr. Hopenfeld referred to a situation at a prototype sodium-cooled reactor and simply stated that

there are many situations in BWRs where loose parts "would cause interference." Tr. 1246 (Hopenfeld). Dr. Hopenfeld did not provide any examples where loose parts from the steam dryer caused interference in a BWR reactor, resulting in a public safety hazard. Tr. 1246 (Hopenfeld).

219. Dr. Hopenfeld further testified that if a part does break loose from the dryer it could interfere with the water that comes out of the spray nozzle or the whole structure could fall on the core. Tr. 1255 (Hopenfeld). But again, he did not provide any examples. *Id.* Dr. Hopenfeld further speculated that it was feasible for a loose part to prevent a relief valve from opening, causing a public safety hazard. Tr. 1247 (Hopenfeld); NEC-JH_54 at 1.

220. The Staff disagreed with Dr. Hopenfeld. Mr. Scarbrough stated he is aware of no mechanism by which loose parts would block an inlet flow for cooling water. Tr. 1256 (Scarbrough). Mr. Scarbrough further testified that loose parts would not interfere with relief valves because there is no driving head to push a loose part into the relief valve branch line if the valve is not open. Tr. 1257 (Scarbrough).

221. Dr. Hopenfeld also postulated that a loss of coolant accident ("LOCA") would cause steam dryer failure which could interfere with safe shutdown of the plant. Tr. 1250-51 (Hopenfeld). Dr. Hopenfeld was, however, not able to clearly articulate his concern. Tr. 1250-1251 (Hopenfeld).

222. Mr. Scarbrough again disagreed, testifying that he was not aware of any situation where the generation of loose parts following a LOCA would exacerbate the accident and/or prevent a safety related component from performing its intended function. Tr. 1253 (Scarbrough). Moreover, Mr. Scarbrough stated that he was not aware of any "scenario by which a loose part from the dryer could interfere with injection of cooling water following a LOCA." Tr. 1254 (Scarbrough response to J. Reed's question); Tr. 1257 (Scarbrough).

Furthermore, Mr. Scarbrough testified that he was not aware of a requirement to consider failure of the steam dryer in association with a loss of coolant accident. Tr. 1251-52 (Scarbrough).

223. Finally, Mr. Hoffman stated that it is Entergy's position that "the monitoring will detect dryer degradation long before" loose parts are generated. Tr. 1296 (Hoffman). Mr. Hoffman further testified that if there is dryer degradation, it would not progress rapidly, so Entergy would "be able to detect and respond prior to the generation of a loose part." Tr. 1297 (Hoffman).

b. Board Findings

224. The Board finds that NEC has presented no credible evidence to indicate that a public safety hazard would result if the dryer failed and a loose part was released. The Board finds the Staff's testimony that there is no mechanism by which a loose part could interfere with inlet flows, relief valves, or even a LOCA situation persuasive. Furthermore, the Board acknowledges that there is no regulatory requirement for a licensee to consider failure of the steam dryer simultaneously with a LOCA. Finally, the Board finds that Entergy has demonstrated that its monitoring program will provide early warning of potential dryer degradation, providing Entergy with ample time to respond prior to the generation of loose parts.

F. Summary of Board Findings of Fact on NEC Contention 3

225. Entergy's SDMP, Revision 3 provides for continuous monitoring of plant parameters and periodic inspections throughout the period of extended operation.

226. NEC has failed to provide any probative evidence to suggest that additional and practical monitoring techniques are available. It is not feasible to monitor stresses directly on the stream dryer. Furthermore, the Board finds that it is not necessary to measure stresses, because the stress on the steam dryer is and will continue to be below the ASME Code endurance limits.

227. Furthermore, the Board finds that Vermont Yankee's steam dryer is not susceptible to cracking due to flow-induced vibration. Post-EPU inspections confirm that no fatigue cracks have occurred and the identified IGSCCs have shown no growth.

228. The Board finds that in the unlikely event there is dryer degradation, the monitoring program will provide sufficient warning allowing Entergy ample time to mitigate the situation before the potential generation of loose parts.

229. Finally, the Board finds that Entergy has provided sufficient information to indicate that Vermont Yankee personnel reviewing plant monitoring data are qualified and that the monitoring program implementation procedures are adequate.

G. NEC Contention 3 Conclusions of Law

230. The Board has considered all of the evidence presented by the parties on NEC Contention 3 and the hearing record, consisting of the filings of the parties in this proceeding, the orders issued by this Board, the exhibits received in evidence and the transcript of the proceeding. Based on a review of the entire record in this proceeding, consideration of the proposed findings of fact and conclusions of law submitted by the parties, and based upon the findings of fact set forth above, which are supported by reliable, probative and substantial evidence in the record, the Board has decided all matters in controversy concerning this contention in favor of Entergy and reach the following conclusions.

231. Pursuant to 10 C.F.R. § 54.21, Entergy is required to demonstrate that the steam dryer aging management program demonstrates that the effects of aging will be adequately managed so that the intended function will be maintained consistent with the CLB for the period of extended operation.

232. Pursuant to 10 C.F.R. § 54.29, as pertinent here, a renewed license may not be issued unless actions have been identified or have been or will be taken with respect to the

steam dryer, which is not a safety-related component, such that there is reasonable assurance that failure of the steam dryer will not interfere with the operation of safety-related components and that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB.

233. Entergy has demonstrated that its program for continuous monitoring and periodic inspection of the steam dryer, which is part of its CLB, is adequate to manage steam dryer structural integrity during the period of extended operation pursuant to 10 C.F.R. Part 54. Entergy demonstrated that its monitoring program is capable of detecting potential dryer degradation and will provide enough warning for Entergy to analyze and mitigate the situation, minimize the potential for damage and loose parts. In addition, Entergy's inspection program provides assurance that the dryer is not and will not be susceptible to damage from flow-induced vibration. Thus, NEC Contention 3 is resolved in favor of Entergy.

234. All issues, motions, arguments, or proposed findings presented by the parties regarding NEC Contention 3 but not addressed herein have been found to be without merit or unnecessary for this decision.

VI. NEC CONTENTION 4

A. Statement of Issue

235. The issue raised by NEC Contention 4 is whether Entergy's plan to monitor and manage the aging of plant piping due to flow-accelerated corrosion at Vermont Yankee is not adequate because it relies on CHECWORKS, an "empirical code," used to determine the scope and frequency of inspection of susceptible components, a code which "must be continuously updated with plant-specific data," and a code that "has not been benchmarked with data" reflecting parameter changes associated with Vermont Yankee's EPU. *See Vermont Yankee Nuclear Power Station*, LBP-06-20, 64 NRC at 192-94.

236. Specifically, NEC asserted that the regulations in 10 C.F.R. § 54.21(a)(3) and 10 C.F.R. § 54.29(a) taken together require Entergy to establish "[a]n aging management program adequate to provide reasonable assurance that, consistent with the CLB, the minimum wall thickness of plant equipment vulnerable to flow-accelerated corrosion (FAC) will not be reduced by FAC to below ASME code limits throughout the twenty-year period of extended operations." NEC Statement of Position at 7-8.

B. Witnesses

237. During the hearing a total of seven witnesses appeared on behalf of the parties: two on behalf of Entergy, two on behalf of the Staff, and three on behalf of NEC. Pre-filed direct testimony was submitted by all seven witnesses.[45] Staff and NEC witnesses also submitted pre-filed rebuttal testimony.[46]

238. Entergy presented the initial testimony of two qualified expert witnesses: James C. Fitzpatrick and Dr. Jeffrey S. Horowitz. Dr. Jeffrey S. Horowitz has more than 36 years of experience in the field of nuclear energy and related disciplines, which includes

---

[45] Entergy: Joint Declaration of Jeffery S. Horowitz and James C. Fitzpatrick on NEC Contention 4 – Flow-Accelerated Corrosion ("Horowitz-Fitzpatrick Decl."), Post Tr. 1427.

NEC: Direct Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3, and 4, ("Hopenfeld Decl."), Post Tr. 779; Pre-Filed Direct Testimony of Dr. Rudolf Hausler Regarding NEC Contention 4 ("Hausler Decl."), Post Tr. 1437; Pre-filed Direct Testimony of Ulrich Witte Regarding NEC Contention 4 ("Witte Decl."), Post Tr. 1439.

Staff: Affidavit of Kaihwa R. Hsu and Jonathan G. Rowley Concerning NEC Contention 4 (Flow Accelerated Corrosion) ("Staff Direct Testimony on Contention 4"), Post Tr.1432.

[46] Pre-filed Rebuttal Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3, and 4, Post Tr. 779 ("Hopenfeld Rebuttal"); Pre-Filed Rebuttal Testimony of Dr. Rudolf Hausler Regarding NEC Contention 4 ("Hausler Rebuttal"), Post Tr.1437; Pre-filed Rebuttal Testimony of Ulrich Witte Regarding NEC Contention 4 ("Witte Rebuttal"), Post Tr. 1439; NRC Staff Rebuttal Testimony of Kaihwa R. Hsu Concerning NEC Contention 4 ("Staff Rebuttal Testimony on Contention 4"), Post Tr.1432

22 years of experience specializing in FAC and nuclear safety analysis. Exh. E4-02. He developed the computer programs CHEC (Chexal-Horowitz Erosion Corrosion) in 1987, CHECMATE (Chexal-Horowitz Methodology for Analyzing Two-Phase Environments) in 1989, and CHECWORKS (Chexal-Horowitz Engineering Corrosion Workstation) in 1993. *Id.* Dr. Horowitz has performed, by himself or with another engineer, audits of the FAC programs at over fifty nuclear units in the United States and Canada, including a FAC program audit at Vermont Yankee, in April 2007. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A7 pp.4-5. Dr. Horowitz played a significant role in drafting Nuclear Safety Analysis Center ("NSAC")-202L, entitled "Recommendations for an Effective Flow-Accelerated Corrosion Program,"[47] and each of its three revisions, which has become the most important standard-setting document for the conduct of FAC control programs in the United States. *Id.* at A8. Finally, Dr. Horowitz has authored numerous articles and given numerous presentations regarding FAC. *Id.* at A9.

239. Mr. Fitzpatrick is currently employed by Areva, NP as an Engineering Supervisor. Exh. E4-03. Prior to March of 2008, Mr. Fitzpatrick was employed by Entergy as a Senior Lead Engineer in the Design Engineering Department at Vermont Yankee. *Id.* In that capacity, Mr. Fitzpatrick provided support to Vermont Yankee's license renewal application in the areas of metal fatigue and flow-accelerated corrosion. *Id.* Mr. Fitzpatrick's involvement with FAC issues dates back to 1987, when he assisted in responding to NRC Bulletin 87-01 that was issued following the FAC accident at Surry in December 1986. Horowitz-Fitzpatrick Decl., Post

---

[47] NSAC was developed by Electric Power Research Institute ("EPRI"), working with members of the CHECWORKS users group ("CHUG"), to develop a set of "recommendations to help utility personnel design and implement a comprehensive FAC mitigation program." Exh. E4-07 at v. *See also* Horowitz-Fitzpatrick Decl. Post Tr. 1427, at A8, p. 5 (stating that the guide is designed to help utilities improve and standardize their FAC programs).

Tr. 1427, at A15. Mr. Fitzpatrick preformed the first modeling of Vermont Yankee using EPRI's CHEC code in 1989, and in 1990, he developed Vermont Yankee's Piping Erosion-Corrosion Inspection Program, which involved modeling the plant using the CHECMATE code. *Id.* Between 1989 and 2007, Mr. Fitzpatrick either provided engineering support or was responsible for implementing Vermont Yankee's FAC program. *Id.* Mr. Fitzpatrick holds BS and MS degrees in civil engineering and has over 30 years of experience in design, construction and modification of nuclear power plant structures, including more than 20 years of experience in operating plant engineering support. Exh. E3-04.

240. NEC presented three witnesses: 1) Dr. Joram Hopenfeld, 2) Dr. Rudolph Hausler, and 3) Mr. Ulrich K. Witte.[48] Dr. Joram Hopenfeld, a professional consultant, holds BS, MS, and PhD degrees in engineering. Exh. NEC-JH_02. He has 45 years of experience in the areas of thermal hydraulics, materials, corrosion, radioactivity transportation, instrumentation, PWR steam generating testing and accident analysis. *Id.* Dr. Hopenfeld was employed by the NRC for nearly 20 years, during which time he worked on matters related to PWR steam generators. *Id.* Since his departure from the agency in 2001, Dr. Hopenfeld has operated a small corporation, Noverflo, which is developing fiber optic sensors for the oil and gas and environmental monitoring industries, and has provided consulting services to law firms and citizens groups. *Id.*

241. Dr. Rudolph H. Hausler holds BS and MS degrees in chemical process

---

[48] Although NEC submitted testimony from Ulrich Witte concerning Contention 4, the Board found, based upon motions in limine filed by Entergy and the Staff that Mr. Witte was not qualified to testify fully on matters regarding Contention 4, and therefore struck part of his pre-filed testimony. *See* Limine Order at 7-8, Attachments 1 & 2.

technology and a PhD in chemical engineering. Exh. NEC-RH_02. For over thirty years he planned, conducted, and directed advanced chemical research focused on oil production and processing additives and has acquired expertise in corrosion prevention, chemical inhibition, and materials selection, failure analysis, trouble shooting and economic analysis. *Id.* Dr. Hausler has also consulted with major oil companies on selection, testing and application of Oil Field Chemicals, primarily corrosion inhibitors. *Id.*

242. NEC's third witness, Mr. Witte, holds a BA in physics and has completed senior level and graduate course work in mechanical engineering and electrical engineering. Exh. NEC-UW_02. Mr. Witte has over twenty-six years of professional experience in engineering, configuration management, licensing, and regulatory compliance of large scale commercial nuclear facilities. *Id.* This includes management and implementation of design change control programs, engineering standards programs, multi-department/multi-functional licensing initiatives, plant design basis, and engineering process improvement programs for six energy companies operating seven nuclear power plants. *Id.*

243. The Staff presented two witnesses, Mr. Jonathan G. Rowley and Mr. Kaihwa R. Hsu. Mr. Rowley holds BS and MS degrees in materials science and engineering. *See* Staff Direct Testimony NEC Contention 3, Post Tr. 1190, at Statement of Professional Qualifications of Jonathan G. Rowley. He has over 14 years of experience in materials science and engineering and over five years of experience in the nuclear reactor regulation. *Id.* Mr. Rowley also has significant experience in materials engineering and license renewal and is currently a Project Manager in the Division of License Renewal, Office of Nuclear Reactor Regulation at the NRC. *Id.*

244. Mr. Kaihwa R. Hsu holds BS and MS degrees in civil engineering. *Id.* at Statement of Professional Qualifications of Kaihwa R. Hsu. Mr. Hsu is currently employed by

the NRC as a Senior Mechanical Engineer in the Division of Engineering, Office of New Reactors. *Id.* Previously, Mr. Hsu was employed by the NRC in the Division of License Renewal in the Office of Nuclear Reactor Regulation. *Id.* Mr. Hsu has over 26 years of experience in the nuclear power industry, including 22 years as a principal engineer for Westinghouse Electrical Company. *Id.* While at Westinghouse, Mr. Hsu was involved in developing a computer code, Corrosion Erosion Monitoring System ("CEMS"), to manage FAC for nuclear power plants. Staff Direct Testimony on Contention 4, Post Tr. 1432, at A10.

245. The Board found the witnesses presented by Entergy, the Staff, and NEC to be qualified to present testimony on the areas they addressed. However, the Board disqualified Mr. Witte from testifying as to the predictive accuracy of the CHECWORKS model, the requirements necessary to benchmark it, and other technical aspects of predicting and modeling FAC. *See* Limine Order at 7-8. The Board gave extra weight to Dr. Horowitz's testimony as he designed and implemented the CHECWORKS computer program.

A. Definition of Flow Accelerated Corrosion

1. Evidence

246. The parties disagreed about the proper definition of FAC. NEC's witness Dr. Hausler contended that "erosion-corrosion, impingement and cavitation are extensions of FAC as the local flow intensity due to turbulence increases. The transition from one to the others is continuous and difficult to identify." Hausler Rebuttal, Post Tr.1437, at A6. *See also* Exh. NEC-RH_05 at 4-7; Hopenfeld Rebuttal, Post Tr. 779, at A45.

247. Entergy's witness, Dr. Horowitz, testified that flow accelerated corrosion "is a degradation mechanism that attacks carbon steel piping and vessels exposed to moving water or wet steam." Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A5. Dr. Horowitz explained that FAC "is a dissolution of the iron oxide coating from the steel surface and if it continues unabated

it will eventually result in rupture." Tr. 1443 (Horowitz). If FAC is not detected, Dr. Horowitz explained that "piping or vessel walls will become progressively thinner, normally globally" until there is a rupture. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A5 p.3. Dr. Horowitz explained that the global nature of FAC will cause a rupture whereas the localized nature of mechanisms like erosion will cause a leak. *Id.*

248. As defined in the "Electric Power Research Institute (EPRI) Recommendations For An Effective Flow Accelerated Corrosion Program (NSAC-202L-R3)," FAC is:

> sometimes referred to as flow-assisted corrosion or erosion-corrosion—leads to wall thinning (metal loss) of steel piping exposed to flowing water or wet steam. The rate of metal loss depends on a complex interplay of many parameters such as water chemistry, material composition, and hydrodynamics. Carbon steel piping components that carry wet steam are especially susceptible to FAC and represent an industry wide problem. Experience has shown that FAC damage to piping at fossil and nuclear plants can lead to costly outages and repairs and can affect plant reliability and safety. EPRI and the industry as a whole have worked steadily since 1986 to develop and refine monitoring programs in order to prevent FAC-induced failures.

Exh. E4-07 at v.

249. Entergy witness, Mr. Fitzpatrick testified that, within the context of the Vermont Yankee FAC program, flow accelerated corrosion does not include impingement or cavitation. Tr. 1471 (Fitzpatrick); Horowitz-Fitzpatrick Decl. Post Tr.1427, at A46.

250. Dr. Hopenfeld disagreed with the above definition of FAC provided by Entergy's experts, stating that he could not separate mechanical erosion from chemical erosion. Tr. 1478-81 (Hopenfeld).

251. In response to NEC's concerns about the definition of FAC, Entergy agreed that mechanical mechanisms such as local corrosion, erosion corrosion, impingement or cavitation cause wear in plant piping Tr. 1471 (Fitzpatrick). Mr. Fitzpatrick testified that Entergy uses UT

measurements to measure the remaining wall thickness of the pipe. Tr. 1471-72 (Fitzpatrick). These measurements do not distinguish how the thinning of the pipe has occurred, they simply detect wall loss. *Id.* Entergy explained that the main purpose of the FAC program is to determine whether pipes are thinning, regardless of how it happens. Tr. 1472 (Fitzpatrick). Dr. Horowitz further explained that the key to locating mechanical erosion is through actual operating experience. Tr. 1512 (Horowitz).

252. The Staff agreed with Entergy that the FAC program at Vermont Yankee includes taking UT measurements. Tr. 1510 (Hsu). These measurements do not distinguish between loss of material due to mechanical mechanisms from loss of material due to chemical mechanisms. *Id*.

2. Board Findings

253. The Board finds that flow accelerated corrosion is defined as the dissolution of the iron oxide coating from the steel surface and represents an industry wide problem. The Board further finds that differences between the parties as to the precise definition of FAC are not material because the UT measurements used to identify pipe thinning do not distinguish between the erosion mechanisms.

D. Vermont Yankee's Flow Accelerated Corrosion Program

1. Description of the Program

254. Entergy's expert, Mr. Fitzpatrick, testified that, as stated in Section B.1.13 of the LRA (Exh. E4-04), Vermont Yankee's flow-accelerated corrosion program is consistent with the program described in NUREG-1801, Section XI.M17, Flow Accelerated Corrosion (Exh. E4-05). Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A17. Entergy's proposed AMP is actually an existing program that will continue into the period of extended operation. Tr. 1502 (Fitzpatrick); Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A19. Mr. Fitzpatrick testified that there are no

exceptions in the LRA to the guidance in NUREG-1801 with respect to FAC. *Id.* at A17.

255. Vermont Yankee's FAC program (set forth in Entergy Procedure EN-DC-315, Rev. 0, Exh. E4-06) has been revised as necessary over time to conform to the recommendations in the various revisions to EPRI's NSAC-202L document. *Id.* The current program has been revised to substantially follow the most recent version of NSAC-202L, NSAC-202L-R3 (Exh. E4-07). *Id.*

256. Entergy's witness Mr. Fitzpatrick testified that Vermont Yankee's FAC Program manages the effects of aging through (a) analyses to determine critical locations; (b) performance of baseline inspections to determine the extent of thinning at these locations; and (c) performance of follow-up inspections to confirm the predictions, or repair or replacement of components as necessary. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A18.

257. Consistent with NRC guidance recommending the use of a predictive computer program (*see* Exh. E4-05), Vermont Yankee's FAC program uses CHECWORKS' FAC wear rate analysis as a tool in planning inspections, evaluating inspection data, and managing inspection data. *Id.* at A18, A21.

258. Consistent with NSAC-202L, Vermont Yankee's FAC program includes procedural and administrative controls to ensure the structural integrity of all carbon steel piping containing high-energy fluids is maintained. *Id.* at A19. NSAC-202L contains detailed instructions on how inspections should be conducted and how inspection data should be evaluated; acceptance criteria for inspection components; criteria for the disposition of components failing to meet acceptance criteria; sample expansion criteria; and instructions for incorporating inspection data into the CHECWORKS model. *Id.*

259. Accordingly, inspections performed under Vermont Yankee's FAC program conform to the recommendations in NSAC-202L. Horowitz-Fitzpatrick Decl., Post Tr. 1427,

at A20. Inspection locations at Vermont Yankee are selected based upon the following factors articulated in NSAC-202L: "(1) pipe wall thickness measurements from past outages; (2) predictive evaluations performed using the CHECWORKS computer code; (3) industry experience related to FAC; (4) results from other plant inspection programs; and (5) engineering judgment." *Id.* at A40. FAC engineers use CHECWORKS to help them determine "the most likely places for FAC to occur, and thus, the key locations to inspect for pipe wall thinning." *Id.* CHECWORKS is just one of the tools that Entergy will use for that purpose. *Id.*

260. Vermont Yankee conducts FAC inspections every outage. Tr. 1569 (Fitzpatrick). As an added measure of conservatism, Entergy has increased the number of inspections by 50% since the power uprate "to get more data to feed into CHECWORKS and to have more data with power uprate flows to develop a level of confidence in measured […] wearing." Tr.1549 (Fitzpatrick); *see also* Tr. 1685 (Fitzpatrick).

2. Alleged Inadequacies in the Vermont Yankee FAC Program

a. Evidence

261. NEC asserted that Entergy's FAC program at Vermont Yankee is inadequate because Entergy's own documents indicate that there are deficiencies in the program. Exh. NEC-UW_03 at 15 (citing E4-26, QA-8-2004-VY-1 ("2004 QA Report")).

262. In response, Mr. Fitzpatrick stated that the 2004 QA Report Mr. Witte relied on does state that there were administrative and documentation issues in the FAC program. Exh. NEC-UW_09 at 2. Mr. Fitzpatrick explained, however, that the referenced 2004 QA Report indicated unsatisfactory results because Entergy personnel did not enter the necessary data into the plant's data management system and that the draft report was not completed in a timely fashion. Tr. 1585-86, 1588 (Fitzpatrick).

263. Mr. Fitzpatrick further explained that in the event information was not updated in

time for the next refuelling outage and a problem was identified thereafter, such that a pipe might reach its critical level before the next scheduled outage, Entergy would address the issue through its corrective action program. Tr. 1594 (Fitzpatrick). Mr. Fitzpatrick stated that, if necessary, Vermont Yankee would reduce power in order to perform an inspection prior to the next refuelling outage. Tr. 1594 (Fitzpatrick).

264. In addition, NEC asserted that Entergy's FAC program has not been implemented consistent with industry guidance. Witte Decl., Post Tr. 1439, at A7.

265. The Staff reviewed Entergy's program and found that the FAC Program at Vermont Yankee is in fact consistent with the program described in NUREG-1801, Section XI.M17 (Exh. E4-04). Staff Exh. 1 at 3-15, 3-17. This means, that Entergy's FAC program implements the guidelines of NSAC-202L. *See* Exh. E4-05. This conclusion was based on the Staff's 2006 audit of Entergy's FAC program. Staff Exh. 1 at 3-15, 3-17.

266. Finally, NEC also raised concerns regarding the basis for CHECWORKS' guidelines for grid selection. Exhs. NEC-JH_01 at 12 and NEC-RH_03 at 13-15. NEC questioned the grid size recommendations and the guidelines for selection of the grid sizes. Exh. NEC-JH_36 at 7, 14-16.

267. In response, Mr. Fitzpatrick testified for Entergy that the grid sizes used at Vermont Yankee to take the ultrasonic technique ("UT") measurements are those recommended in NSAC-202L. Tr. 1663-64 (Fitzpatrick). Specifically, the grid standard used at Vermont Yankee is specified by an engineering standard, "Flow Accelerated Corrosion Component Scanning and Gridding Standard" (Exh. E4-25). Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A56, p.41. As an additional step, rather than recording the thickness reading at particular grid points, Vermont Yankee scans components in their entirety by moving the ultrasonic transducer over the entire surface within a grid square. *Id.* at A56, p.42. Vermont Yankee records the

minimum reading anywhere within a grid square. This ensures that the thinnest readings for the component are found. *Id; see also* Tr. 1560 (Fitzpatrick).

b. Board Findings

268. The Board finds that Entergy's Flow-Accelerated Corrosion Program at Vermont Yankee is consistent with the program described in NUREG-1801, Section XI.M17, and therefore applicable industry guidance in NSAC-202L, Exh. E4-05. The Board also finds that NEC has not provided any credible evidence in support of its critique of the grid size used for UT measurements at Vermont Yankee. Furthermore, the Board finds that Entergy has adequately addressed the program implementation issues raised by NEC.

E. CHECWORKS

1. Description of CHECWORKS

269. The current CHECWORKS program evolved originally from the use of corrosion data mostly from plants and laboratory studies in Europe, using a correlation to relate the plant conditions with rates of corrosion. Tr. 1445-46 (Horowitz). As a result of the pipe rupture at the Surry plant, EPRI and the Nuclear Utility Management and Resources Council (NUMARC) committed to develop a computer program to assist utilities in selecting inspection locations to look for flow accelerated corrosion. Tr. 1444 (Horowitz).

270. CHECWORKS is a multi-purpose computer program designed to assist FAC engineers in identifying potential locations of FAC vulnerability. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A26. CHECWORKS uses plant-specific inputs defining: (1) the oxygen concentration (e.g., main steam nozzle); (2) thermodynamic conditions; and (3) flow rates. *Id.* at A27 (Horowitz). These inputs are applied along with plant specific component geometries into the CHECWORKS model to obtain an estimated FAC wear rate for each modeled

component. *Id.* at A27. Dr. Horowitz testified that the CHECWORKS program was designed to handle changes in plant operating conditions. Tr. 1451-52 (Horowitz); *see also* Horowitz-Fitzpatrick Decl., Post Tr. 1432, at A34.

271. Dr. Horowitz explained that CHECWORKS is used to model a particular nuclear unit by specifying global plant data, including a schematic representation of the plant heat balance diagram ("HBD") (i.e*.,* major lines and connectivity of the power producing portion of the nuclear plant). Horowitz-Fitzpatrick Decl., Post Tr.1432, at A28. The user inputs data into the model on thermodynamic conditions, oxygen concentration conditions, and water chemistry. *Id.* Based on these inputs, the user conducts a "Pass 1 Analysis" to report predicted wear rates. *Id.* The "Pass 1 Analysis" does a prediction using the correlation without any consideration of inspection data and thus just gives a raw prediction. Tr. 1452 (Horowitz). No inspection data is necessary for the "Pass 1 Analysis." Horowitz-Fitzpatrick Decl., Post Tr. 1432, at A28. The results of the "Pass 1 Analysis," along with operating experience from similar facilities, can then be used by the FAC engineer to generate a list of components for inspection. *Id.*

272. When inspection data is available, the FAC engineer may perform a "Pass 2 Analysis," to compare the predicted amount of wear to the actual amount of wear. Tr. 1452-53. The "Pass 2 Analysis" compares the predicted wear to the measured wear and, using statistical methods, determines a line correction factor that can be applied to all components on a given pipe line regardless of whether they were inspected. Horowitz-Fitzpatrick Decl., Post Tr. 1432, at A28.

273. Dr. Horowitz testified that CHECWORKS is simply a tool to help the engineer select locations for inspection. Tr. 1452 (Horowitz). CHECWORKS does not identify problem areas; operating experience will identify these areas. Tr. 1512 (Horowitz). Additionally, according to Mr. Fitzpatrick, the FAC program engineer will document the basis for including

inspection components in the scoping document every outage. Tr. 1575 (Fitzpatrick). The engineer will include an explanation for why he or she is inspecting components now and will determine what will be included in future inspections. *Id.*

274. Although CHECWORKS is not the only program available, Entergy has elected to use CHECWORKS because it has been accepted by the industry - all the nuclear units in the United States, Canada and Mexico use CHECWORKS. Tr. 1548-49 (Horowitz, Fitzpatrick).

2. Alleged Inadequacies of CHECWORKS Generally

a. Evidence

275. Dr. Hopenfeld questioned the validity of CHECWORKS, noting that the NRC has specific guidelines for computer codes used for licensing bases. Dr. Hopenfeld stated that he could not find any indication that CHECWORKS meets the Commission's guidelines. Hopenfeld Rebuttal, Post. Tr. 779, at A41.

276. Dr. Horowitz responded that the utility companies use the CHECWORKS program as a tool to provide information to FAC engineers. Horowitz-Fitzpatrick Decl. Post Tr. 1432, at A26. CHECWORKS is not used for nuclear design or applicability, it is simply used as a predictive tool; the information produced by CHECWORKS is not used for functions typically covered by nuclear QA programs. Tr. 1600 (Horowitz).

277. Dr. Hopenfeld further testified that CHECWORKS is an empirical model that must be calibrated with plant specific data. Hopenfeld Rebuttal, Post Tr. 779, at A46. Dr. Hopenfeld contended that if relevant plant parameters change, the model must be recalibrated based on sufficient inspection data to reestablish reliable FAC trends under the new operating conditions. Exhs. Hopenfeld Decl., Post Tr. 779, at A21, A22; Exh. NEC-JH_36 at 6-8.

278. Dr. Horowitz responded that the use of CHECWORKS does not change as a result of a power uprate. Dr. Horowitz explained:

> [a]ll that needs to be done is to update plant-specific inputs into the CHECWORKS program. When a power uprate is implemented, a user simply does what he would normally do as part of any Pass 2 Analysis – update the relevant variables (e.g., thermodynamic conditions, temperature, oxygen concentration, etc.), and let the program calculate the predicted FAC wear. The Pass 2 Analysis can be used as a planning tool by performing it in advance of the uprate to determine if, under uprate conditions, systems and subsystems would experience significantly greater FAC rates than those predicted before the uprate. CHECWORKS was specifically designed to accommodate power uprates and is routinely used throughout the U.S. nuclear industry for this purpose.

Horowitz-Fitzpatrick Decl., Post Tr. 1432, at A33; *see also* Exh. E4-09 at ¶¶19, 20.

279. NEC, through Dr. Hopenfeld, questioned CHECWORKS' ability to predict FAC. Hopenfeld Decl., Post Tr. 779, at A23; Tr. 1601-02 (Hopenfeld). Dr. Hopenfeld testified that he identified a number of problems with CHECWORKS, including: 1) the relationship between velocity and corrosion rate; 2) the equation relating local corrosion rates to total corrosion rates; 3) basing the relationship between corrosion and velocity on the dissolution of copper in hydrochloric acid; 4) the accuracy of corrosion rate predictions. Tr. 1619-22 (Hopenfeld). He asserted that figures in Entergy Exhibits E4-08, E4-30, E4-29 at 10, and Exhibit NEC JH-37 at Figure 5 support his assertions. Tr. 1622 (Hopenfeld).

280. Dr. Horowitz methodically dismissed Dr Hopenfeld's concerns: first, Dr. Horowitz addressed Dr. Hopenfeld's assertion that the relationship between velocity and corrosion rate is not linear, testifying that the initial laboratory data indicated that the relationship between velocity and corrosion rate is in fact linear. Tr. 1625-26 (Horowitz). If the relationship was, as Dr. Hopenfeld suggests, corrosion as a power of 2.4 to 6 of the velocity, the model would not have been able to track reasonably well, what was actually happening in plants. *Id*. Dr. Horowitz explained that the linear dependency matches the French model which is generally accepted for FAC. *Id*. at 1626.

281. Second, Dr. Horowitz responded to Dr. Hopenfeld's testimony that the equation relating local corrosion to total corrosion is not correct. Tr. 1627 (Horowitz). Dr. Horowitz stated that Dr. Hopenfeld's assertion is based on an equation in the FAC book (E4-08) at Figure 7-2. *Id.* Dr. Horowitz testified that that equation (A = A + BA) is not used in CHECWORKS, and is therefore irrelevant. Tr. 1627 (Horowitz).

282. Third, Dr Horowitz responded to Dr. Hopenfeld's assertion that the relationship between corrosion and velocity in CHECWORKS is incorrect because it is based on the dissolution of copper in hydrochloric acid but the material at issue is not copper. Tr. 1619 (Hopenfeld). Dr. Horowitz explained that the copper tests referred to by Dr. Hopenfeld were not used to establish wear rates or to define geometry tables. Tr. 1627 (Horowitz). The copper tests were used as a fast way to test the effect of different geometries on wear rates. *Id.* Dr. Horowitz testified that while there were differences between copper and steel, the differences were not qualitative, and only the qualitative results were used. Tr. 1627-28 (Horowitz). Furthermore, all the geometry factors in CHECWORKS come from plant data. *Id.*

283. Fourth, Dr. Horowitz responded to Dr. Hopenfeld's criticism of Entergy's FAC predictions that the graphs Dr. Hopenfeld referenced were graphs of data from the feedwater line. Tr. 1630 (Horowitz, referring to Exh. E4-30 at 57). Referring to the graph on page 57 of Exhibit E4-30, Dr. Horowitz explained that there is very little wear in the feed water line. Tr. 1629 (Horowitz). He explained that the slow wear rate is indicated by the low line correction factor, i.e. .0.196, as opposed to the normal range of 0.50 to 2.5. Tr. 1631 (Horowitz). Dr. Horowitz further explained that the low line correction factor indicates that the model is not performing well for this line, but that this is not unique to Vermont Yankee; it's a common problem for BWR feedwater lines. Tr. 1632 (Horowitz). Dr. Horowitz testified that EPRI has recognized this problem and is investigating the issue. Tr. 1631 (Horowitz); Tr. 1636 (Horowitz response to

J. Wardwell question). Mr. Fitzpatrick explained that this problem does not affect other lines in the CHECWORKS program because each line is evaluated separately. Tr. 1636 (Fitzpatrick).

284. Dr. Horowitz testified that "[w]hat the program does for each analysis line is presents predicted wear rate, and predicted total wear for the component. For components with measured data, it also compares the predicted wear with the measured wear at the time of that inspection." Tr. 1646-47 (Horowitz).

285. Lastly, Dr. Horowitz explained that the correlations in the CHECWORKS model are based on empirical data; CHECWORKS is built on actual plant data as opposed to theoretical solutions. Tr. 1655-56 (Horowitz).

286. Dr. Hopenfeld asserted that CHECWORKS has not successfully prevented pipe failures due to FAC. To support his position, Dr. Hopenfeld referred to several events at reactors and fossil facilities where FAC was not detected. *See* Exh. NEC-JH_36 at 9-11.

287. However, NSAC-202L, Exh. E4-07 at vi, clearly states that "it will never be possible to prevent all FAC-related leaks and ruptures." *See also* Tr. 1500-01 (Fitzpatrick).

288. Furthermore, Dr. Horowitz testified for Entergy, and Mr. Hsu for the NRC Staff, agreed, that the examples referenced by Dr. Hopenfeld do not involve situations in which the proper use of CHECWORKS or its predecessor programs were ineffective in managing FAC. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A52; Staff Direct Testimony on Contention 4, Post Tr.1432, at A32.

b. Board Findings

289. The Board finds that CHECWORKS was designed to handle changes in plant parameters. The Board finds NEC's assertions that the assumptions in the CHECWORKS model are incorrect unpersuasive in light of Entergy's testimony that CHECWORKS is based on empirical data, not theoretical solutions, and Entergy's testimony explaining that operating

experience confirms the relationship between velocity and corrosion rate assumed by the CHECWORKS model. The Board further finds that there is no credible evidence that CHECWORKS, when properly used, has failed to predict FAC.

3. Alleged Inadequacies in the Use of CHECWORKS at Vermont Yankee

290. NEC contended that Entergy cannot successfully use the CHECWORKS model as part of its FAC program during the renewed license term because it will not be possible to properly calibrate CHECWORKS to EPU operating conditions before expiration of Vermont Yankee's current license. Exh. NEC-JH_36 at 14-16. Dr. Hopenfeld asserted that it would take at least 10-15 years of data to recalibrate CHECWORKS. *Id.* at 25. Another NEC expert, Mr. Witte, testified that "industry guidance" recommends five to ten years of data trending, and because of Vermont Yankee's recent EPU, trending to the high end of that range is appropriate. Exh. NEC-UW-03 at 21 (referencing Exh. NEC-UW_13 at 38). NEC's third witness, Dr. Hausler testified that at least three data points are needed to determine a wear rate for a component. Tr. 1680 (Hausler).

291. The Staff testified that two inspection cycles of data for the same component are usually needed to determine the wear rate following a change in plant parameters. Staff Direct Testimony on Contention 4, Post Tr.1432, at A19. However, in the case of Vermont Yankee only one cycle is needed for trending because the increase in velocity in the main steam and feedwater lines due to the uprate will cause proportional increases in the FAC wear. *Id.* at A20. In other words, Vermont Yankee only needs one cycle of inspection results to confirm FAC wear rates under uprate conditions because the previous inspection data established a baseline and the predicted increase in wear rates due to the uprate was proportional. *Id.* at A20; A24. The 2007 inspection results were consistent with the prediction that the EPU would cause a

proportional increase in wear rates. *Id.* at A37.

292. Mr. Fitzpatrick testified that there will be three inspections between implementation of the EPU and the end of the current license. Horowitz-Fitzpatrick Decl., Post Tr. 1427, at A40. These inspections will yield data for four and a half years at EPU levels. *Id.*

293. Mr. Witte cited the Chockie Group International report for the proposition that at least 5 to 10 years of trending is necessary to recalibrate CHECWORKS. Exh. NEC-UW_13 at 38

294. Mr. Hsu testified for the Staff that this guidance does not support Mr. Witte's assertion. Staff Direct Testimony on Contention 4, Post Tr.1432, at A19. Mr. Hsu explained that the 5-10 year recommendation in the Chockie report is not for trending or preventive maintenance programs. *Id.* The recommendation is for trending the number of work orders for major equipment maintenance over 10-15 years. *Id.* The Chockie report simply does not suggest that 5-10 years of FAC data is needed. *Id.*

295. Entergy rebutted NEC's assertion that benchmarking or recalibration of CHECWORKS is needed following an EPU. Horowitz-Fitzpatrick Decl. Post Tr. 1427, at A34, A41. Dr. Horowitz explained benchmarking or recalibration of CHECWORKS is unnecessary. *Id.* At Vermont Yankee, the new values for flow rate and temperature were used as inputs into CHECWORKS, and CHECWORKS provided FAC rate calculations for the modeled components under the uprated conditions. *Id.* at A41. At Vermont Yankee, only the flow rate and temperature changed due to the power uprate. *Id.* These new values were put into CHECWORKS and new wear rates were calculated for those components at EPU conditions. *Id.* Because flow rate and temperature were the only changes at Vermont Yankee, the calculated FAC wear rates after the uprate will be constant and the effect of the uprate on FAC will be apparent in the first post-uprate inspection. *Id.*

296. Mr. Fitzpatrick further testified that Entergy did not see any significant increase in wear rates in the 2007 inspection and that Entergy does not expect to see any changes in the next two inspections before the period of extended operation. Tr. 1676 (Fitzpatrick). Mr. Fitzpatrick also noted that CHECWORKS' predictions have been conservative and that all the inspection data has shown less wear than CHECWORKS has predicted. Tr. 1596 (Fitzpatrick).

297. Dr. Hausler contended that at least three data points are necessary to establish a wear rate due to uncertainty in UT measurements. Exh. NEC-RH_03 at 13; Tr. 1680 (Hausler). In response, Mr. Fitzpatrick testified that Vermont Yankee's UT probe has an accuracy of +/- 0.004 inch. Tr. 1534 (Fitzpatrick). In addition, Mr. Fitzpatrick stated that Entergy adds a safety factor of ten percent (10%) to wear rates. Tr. 1533 (Fitzpatrick).

298. Mr. Fitzpatrick testified that although additional inspections are not needed to "calibrate" CHECWORKS, Entergy will, as an added measure of conservatism, increase the inspection scope by at least 50% for the first three outages following the EPU. Tr. 1685 (Fitzpatrick); Exh. E4-38. In the last refueling outage prior to EPU, RFO 25 in 2005, there were a total of 35 inspections performed, including 27 large bore inspections. Exh. E4-38. In the first outage since the EPU, RFO 26 in 2007, the inspection scope was increased by more than 50%, there were a total of 63 inspections performed, including 49 large bore inspections. Exh. E4-10. These additional measurements provide additional confirmatory data points for the use of the FAC Program.

299. In addition to increasing the scope of inspections, Mr. Fitzpatrick testified that Entergy has increased the calculated wear rate by 25 percent since the EPU. Tr. 1684 (Fitzpatrick). Mr. Fitzpatrick also noted that "[t]he data that's put into CHECWORKS is usually the minimum [thickness] measurement of all the [thickness] measurements on that pipe . . . ."

Tr. 1560 (Fitzpatrick).

300. Finally, Mr. Fitzpatrick explained that CHECWORKS is a planning tool used to track and trend data. Tr. 1595 (Fitzpatrick). Entergy does not rely solely on CHECWORKS to select inspection locations; Entergy also uses engineering judgement, pervious inspection results, and operating experience from other nuclear power plants. Tr. 1677-78 (Fitzpatrick). In fact, only about a third of the inspection locations are determined by CHECWORKS. *Id.* Furthermore, Mr. Fitzpatrick testified that if Entergy were no longer able to use CHECWORKS as part of its FAC program it would not be problematic. Tr. 1678 (Fitzpatrick response to J. Reed's question). Dr. Hopenfeld agreed that CHECWORKS is not necessary. Tr. 1690 (Hopenfeld stating "that we could get away with[out] CHECWORKS . . . ." (*See* Joint Proposed Transcript Corrections at 38)).

4. Board Findings

301. The Board finds there is no credible evidence supporting NEC's assertion that prolonged benchmarking or recalibration is needed for Entergy to effectively use CHECWORKS as a tool to manage FAC.

F. Summary of Board Findings of Fact on NEC Contention 4

302. CHECWORKS is a tool that Entergy uses to manage FAC. Entergy's FAC program neither relies solely on CHECWORKS nor is it dependent on CHECWORKS.

303. Prolonged benchmarking or calibration of CHECWORKS is not necessary following an EPU.

304. NEC has not provided credible evidence showing that the CHECWORKS model is not a useful tool or that Vermont Yankee cannot use CHECWORKS as part of its FAC program.

G. NEC Contention 4 Conclusions of Law

305. The Board has considered all of the evidence presented on NEC Contention 4 and the hearing record, consisting of the filings of the parties in this proceeding, the orders issued by this Board, the exhibits received in evidence and the transcript of the proceeding. Based on a review of the entire record in this proceeding, consideration of the proposed findings of fact and conclusions of law submitted by the parties, and based upon the findings of fact set forth above, which are supported by reliable, probative and substantial evidence in the record, the Board has decided all matters in controversy concerning this contention in favor of Entergy and reaches the following conclusions.

306. Pursuant to 10 C.F.R. § 54.21(a), Entergy is required to demonstrate that its FAC program will be effective in managing the effects of aging on FAC-susceptible components during the period of extended. Entergy needs to demonstrate that the components will be adequately managed so that the intended functions will be maintained consistent with the current licensing basis during the period of extended operation, as required by 10 C.F.R. § 54.21(a)(3).

307. Pursuant to 10 C.F.R. § 54.29, as pertinent here, a renewed license may not be issued unless actions have been identified and have been or will be taken with respect to the effects of aging on plant piping, such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB.

308. Entergy has demonstrated that the Vermont Yankee FAC program is adequate to monitor and manage thinning of plant piping susceptible to FAC such that the ASME code limits will be maintained during the period of extended operation.

309. All issues, motions, arguments, or proposed findings presented by the parties, but not addressed herein have been found to be without merit or unnecessary for the Board's

decision on Contention 4.

VII. ORDER

For the foregoing reasons, it is hereby ordered that NEC's contentions are resolved in favor of the Applicant, Entergy. This initial decision shall constitute the final decision of the Commission forty (40) days from the date of its issuance, unless, within fifteen (15) days of its service, a petition for review is filed in accordance with 10 C.F.R. § 2.341(b)(1).

It is so ORDERED.

Respectfully submitted,

/RA/

Lloyd B. Subin
Counsel for NRC Staff

/RA/

Mary C. Baty
Counsel for NRC Staff

/RA/

Jessica A. Bielecki
Counsel for NRC Staff

Dated at Rockville, Maryland
this 25th day of August, 2008

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
ENTERGY NUCLEAR VERMONT YANKEE, LLC	)	Docket No. 50-271-LR
AND ENTERGY NUCLEAR OPERATIONS, INC.	)	
	)	
(Vermont Yankee Nuclear Power Station)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of the "NRC STAFF'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW IN THE FORM OF A INITIAL DECISION" in the above-captioned proceeding have been served on the following by electronic mail with copies by deposit in the NRC's internal mail system or as indicated by an asterisk, by electronic mail, with copies by U.S mail, first class, this 25th day of August, 2008.

Alex S. Karlin, Chair
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: ask2@nrc.gov

Office of the Secretary
Attn: Rulemakings and Adjudications Staff
Mail Stop: O-16G4
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: hearingdocket@nrc.gov

William H. Reed*
Administrative Judge
Atomic Safety and Licensing Board
1819 Edgewood Lane
Charlottesville, VA 22902
E-mail: whrcville@embarqmail.com

Marcia Carpentier, Esq.
Atomic Safety and Licensing Board Panel
Mail Stop: T-3F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: mxc7@nrc.gov

Richard E. Wardwell
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: rew@nrc.gov

Sarah Hofmann, Esq.*
Director of Public Advocacy
Department of Public Service
112 State Street - Drawer 20
Montpelier, VT 05620-2601
E-mail: sarah.hofmann@state.vt.us

Office of Commission Appellate Adjudication
Mail Stop: O-16G4
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: OCAAmail@nrc.gov

Peter C.L. Roth, Esq.*
Office of the Attorney General
33 Capitol Street
Concord, NH 3301
E-mail: peter.roth@doj.nh.gov

Ronald A. Shems, Esq.*
Karen Tyler, Esq.
Shems Dunkiel Kassel & Saunders, PLLC
91 College Street
Burlington, VT 05401
E-mail: rshems@sdkslaw.com
Ktyler@sdkslaw.com

David R. Lewis, Esq.*
Matias F. Travieso-Diaz, Esq.
Elina Teplinsky, Esq.
Blake J. Nelson, Esq.
Pillsbury Winthrop Shaw Pittman LLP
2300 N Street, NW
Washington, DC 20037-1128
E-mail: david.lewis@pillsburylaw.com
matias.travieso-diaz@pillsburylaw.com
elina.teplinsky@pillsburylaw.com
blake.nelson@pillsburylaw.com

Anthony Z. Roisman, Esq.*
National Legal Scholars Law Firm
84 East Thetford Rd.
Lyme, NH 03768
E-mail: aroisman@nationallegalscholars.com

/RA/

Mary C. Baty
Counsel for the NRC Staff