LBP-08-25

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:

Alex S. Karlin, Chairman
Dr. Richard E. Wardwell
Dr. William H. Reed

In the Matter of ENTERGY NUCLEAR VERMONT YANKEE, L.L.C., and ENTERGY NUCLEAR OPERATIONS, INC. (Vermont Yankee Nuclear Power Station)	Docket No. 50-271-LR ASLBP No. 06-849-03-LR November 24, 2008

Partial Initial Decision
(Ruling on Contentions 2A, 2B, 3, and 4)

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ABBREVIATIONS

ACM	Acoustic Circuit Model
ACRS	Advisory Committee on Reactor Safety
AEA	Atomic Energy Act
CFD	Computational Fluid Dynamic
AMP	Aging Management Program
ASME	American Society of Mechanical Engineers
BPV	Boiler and Pressure Vessel
BWR	Boiling Water Reactor
BWRVIP	BWR Vessel Internals Program
CFD	Computational Fluid Dynamic
CLB	Current Licensing Basis
CS	Core Spray
CUF	Cumulative Usage Factor
CUFen	Cumulative Usage Factor Environmentally Adjusted
DO	Dissolved Oxygen
DPS	Department of Public Services of the State of Vermont
ECP	Electrochemical Potential
EPRI	Electric Power Research Institute
EPU	Extended Power Uprate
FEIS	Final Environmental Impact Statement
Fen	Environmentally Adjusted Factor
FMP	Fatigue Monitoring Program
FSER	Final Safety Evaluation Report
FW	Feedwater
GALL	Generic Aging Lessons Learned
GDC	General Design Criteria
LOCA	Loss of Coolant Accident
LRA	License Renewal Application
LWR	Light Water Reactor
NEC	New England Coalition, Inc.
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
PEO	Period of Extended Operation
RFO	Refueling Outage
RR	Reactor Recirculation
SDMP	Steam Dryer Monitoring Plan
SIA	Structural Integrity Associates, Inc.
SRP-LR	Standard Review Plan – License Renewal
TLAA	Time-Limited Aging Analyses
UFSAR	Updated Final Safety Analysis Report
UT	Ultrasonic Testing
VYNPS	Vermont Yankee Nuclear Power Station

Partial Initial Decision
(Ruling on Contentions 2A, 2B, 3, and 4)

This partial initial decision[1] concerns an application submitted by Entergy Nuclear Vermont Yankee, L.L.C., and Entergy Nuclear Operations, Inc. (collectively, Entergy) to renew the operating license for the Vermont Yankee Nuclear Power Station (VYNPS) in Windham County, Vermont.[2] The proposed license renewal, if approved, would extend Entergy's license for an additional twenty years beyond the current expiration date of March 21, 2012. The New England Coalition, Inc. (NEC), an environmental organization, and the Department of Public Services of the State of Vermont (Vermont or DPS) challenged the license renewal application (LRA) on several grounds. See LBP-06-20, 64 NRC 131, 140-41 (2006). The Attorney General of the State of New Hampshire (New Hampshire) and the Attorney General of the Commonwealth of Massachusetts (Massachusetts) participated in this adjudicatory proceeding as "interested states" pursuant to 10 C.F.R. § 2.315(c).[3]

During the week of July 21, 2008, this Board held an evidentiary hearing in Newfane, Vermont on three challenges to the issuance of the license renewal.[4] These challenges, referred to as "contentions," are as follows:

> Contention 2A/B:
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> A. [T]he analytical methods employed in Entergy's [environmentally corrected CUFor] CUFen Reanalysis were flawed by numerous uncertainties, unjustified assumptions, and insufficient conservatism, and produced unrealistically

[1] This initial decision is partial because the Board's authorization is contingent on the performance of additional metal fatigue analyses and because Contention 2 is held in abeyance. See infra Part III.C.2.

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

[3] Order (New Hampshire Participation as Interested State) (Nov. 17, 2006) (unpublished); Order (Commonwealth of Massachusetts Participation as Interested State) (May 12, 2008) (unpublished).

[4] Other contentions and challenges were raised by NEC, Vermont, and Massachusetts, but they were resolved prior to the evidentiary hearing.

> 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.

LBP-07-15, 66 NRC 261, 267-68 (2007).

> B. Entergy's Second CUFen Reanalysis neither validates the results of Entergy's First CUFen Reanalysis, nor independently demonstrates that CUFens for all components . . . are less than one.[5]

> Contention 3:
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> 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.

> Contention 4:
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> Entergy's License Renewal Application does not include an adequate plan to monitor and manage aging of plant piping due to flow accelerated corrosion during the period of extended operation.

Id. at 192.

As set forth below, after considering all of the evidence and legal arguments the Board rules as follows. First, with regard to Contentions 2A and 2B, we conclude that Entergy's metal fatigue analyses of the core spray and reactor recirculation outlet nozzles do not comply with relevant requirements and do not provide the reasonable assurance of safety required by 10 C.F.R. §§ 54.21(c)(1) and 54.29. Under these circumstances the Board rules that the license renewal is not authorized and thus cannot be granted until 45 days after Entergy satisfactorily completes these metal fatigue calculations and serves them on the NRC Staff and the other parties herein. Until that time, this proceeding on Contentions 2A and 2B will remain open and Contention 2 will be held in abeyance.

Second, with regard to Contentions 3 and 4, which deal with the aging management programs for the VYNPS steam dryer and for flow accelerated corrosion, respectively, the

[5] New England Coalition, Inc.'s Motion to file a Timely New or Amended Contention (Mar. 17, 2008) at 3 [NEC Motion to File Contention 2B].

Board concludes that these programs comply with the relevant requirements and provide the reasonable assurance of safety required by the regulations. However, to clarify ambiguity in the LRA, our decision with respect to Contention 3 is conditioned on the requirement that Entergy continue to monitor and inspect the steam dryer during the PEO at the intervals specified in GE-SIL-644 Revision 2. Also our findings on Contention 4 rest in part, on certain facts that have been officially noticed under 10 C.F.R. § 2.337(f) and Rule 201(e) of the Federal Rules of Evidence, and therefore any party wishing to challenge such facts may do so either by filing a motion for reconsideration with this Board, or an appeal to the Commission. Absent any such timely motion or appeal, the record with regard to Contentions 3 and 4 is closed.

I. GENERAL BACKGROUND

Entergy filed its LRA for the VYNPS on January 25, 2006. On March 27, 2006, the Commission published a notice of opportunity to request a hearing on the application. 71 Fed. Reg. 15,220 (Mar. 27, 2006).

On May 26, 2006, petitions to intervene and requests for hearing, each including one or more contentions, were filed by several entities, including NEC, Vermont, and Massachusetts.[6] Entergy and the NRC Staff filed answers, arguing that the petitions should be denied because none of the petitioners had submitted an admissible contention as required by 10 C.F.R. § 2.309(a).[7] On June 29 and 30, 2006, NEC, Vermont, and Massachusetts each filed their reply

[6] Petition for Leave to Intervene, Request for Hearing, and Contentions (May 26, 2006) [NEC Petition]; [Vermont] Notice of Intention to Participate and Petition to Intervene (May 26, 2006) [Vermont Petition]; [Massachusetts] Request for a Hearing and Petition for Leave to Intervene with Respect to [Entergy's] Application for Renewal of the Vermont Yankee Nuclear Power Plant Operating License and Petition for Backfit Order Requiring New Design Features to Protect Against Spent Fuel Pool Accidents (May 26, 2006).

[7] Entergy's Answer to [NEC]'s Petition for Leave to Intervene, Request for Hearing, and Contentions (June 22, 2006) [Entergy Answer to NEC]; Entergy's Answer to [Vermont] Notice of Intention to Participate and Petition to Intervene (June 22, 2006); Entergy's Answer to the [Massachusetts] Request for a Hearing, Petition for Leave to Intervene, and Petition for Backfit Order (June 22, 2006); Entergy's Answer to the Town of Marlboro's Request for Hearing (June 14, 2006); NRC Staff Answer to Request for Hearing of [NEC] (June 22, 2006) [Staff Answer to NEC]; NRC Staff Answer to [Vermont] Notice of Intention to Participate and Petition to Intervene

briefs.[8] On August 1 and 2, 2006, the Board heard oral argument in Brattleboro, Vermont on the admissibility of the various proposed contentions. Tr. at 40-452.

On September 22, 2006, the Board admitted four of NEC's six proposed contentions (NEC Contentions 1 through 4)[9] and one of Vermont's three proposed contentions (Vermont Contention 1). LBP-06-20, 64 NRC at 162-67, 175-96. The Board also permitted NEC and Vermont to adopt each other's contentions. Id. at 208-09. The Board found that Massachusetts' one proffered contention failed to meet the requirements of 10 C.F.R. § 2.309(f)(1) and was therefore inadmissible.[10]

Subsequently, two of the five admitted contentions were resolved. On April 11, 2007, the Commission ruled that NEC Contention 1 was not admissible and therefore it was eliminated from this proceeding. CLI-07-16, 65 NRC 371, 375 (2007).

On May 4, 2007, Vermont, on behalf of itself and NEC, and with the agreement of Entergy, filed a joint motion for approval of a settlement agreement and dismissal of Vermont Contention 1.[11] The NRC Staff did not oppose the settlement. Id. at 2. The Board found that

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(June 22, 2006); NRC Staff Answer Opposing [Massachusetts] Request for Hearing and Petition for Leave to Intervene and Petition for Backfit (June 22, 2006); NRC Staff Answer to Town of Marlboro's Request for Hearing (June 22, 2006).

[8] [NEC]'s Reply to Entergy and NRC Staff Answers to Petition for Leave to Intervene, Request for Hearing, and Contentions (June 29, 2006); [Massachusetts] Reply to Entergy's and NRC Staff's Responses to Hearing Request and Petition to Intervene with Respect to Vermont Yankee License Renewal Proceeding (June 30, 2006); [DPS] Reply to Answers of Applicant and NRC Staff to Notice of Intention to Participate and Petition to Intervene (June 30, 2006).

[9] Judge Wardwell filed a dissent concerning the admission of NEC Contention 1, which dealt with thermal discharges and the National Environmental Policy Act. LBP-06-20, 64 NRC at 211.

[10] Id. at 209. The Town of Marlboro, Vermont also filed a request for a hearing, but its contention was denied. Id. at 201.

[11] Joint Motion for Approval of Settlement Agreement and Dismissal of DPS Contention 1 (May 4, 2007).

the proposed settlement agreement conformed to the requirements of 10 C.F.R. § 2.338(g) and (h), approved the settlement agreement, and dismissed Vermont Contention 1.[12]

The disposition of NEC Contention 1 and Vermont Contention 1 left three admitted contentions (Contentions 2, 3, and 4 (formerly "NEC Contentions")), four parties (Entergy, NEC, Vermont, and the NRC Staff), and one interested state (New Hampshire) in the proceeding. Subsequently, Massachusetts re-entered the adjudicatory proceeding as an interested state.[13]

Pursuant to our November 17, 2006, initial scheduling order and 10 C.F.R. § 2.332(d), the evidentiary hearing in this case could not be held until after the NRC Staff issued its Final Environmental Impact Statement (FEIS) and Final Safety Evaluation Report (FSER). Order (Initial Scheduling Order) (Nov. 17, 2006) at 4, 12 (unpublished). The NRC Staff issued the

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[12] Order (Approving Settlement of DPS Contention 1) (May 31, 2007) at 1 (unpublished).

[13] Initially, Massachusetts appealed our denial of its single contention, which alleged that Entergy's environmental report failed to satisfy National Environmental Policy Act (NEPA) because it did not address the environmental impacts of severe spent fuel pool accidents. LBP-06-20, 64 NRC at 152. The Board ruled that, "as a matter of law the contention is not admissible because the Commission has already decided, in Turkey Point, that licensing boards cannot admit an environmental contention regarding a Category 1 issue." Id. at 155 (referencing Florida Power & Light Co. (Turkey Point Nuclear Generating Plants, Units 3 and 4), CLI-01-17, 54 NRC 3 (2001)). On January 22, 2007, the Commission affirmed the denial of Massachusetts' contention. CLI-07-03, 65 NRC 13 (2007), reconsideration denied, CLI-07-13, 65 NRC 211 (2007). On April 8, 2008, the U.S. Court of Appeals for the First Circuit affirmed the denial of Massachusetts contention, ruling that Massachusetts had chosen the wrong path in seeking to raise the spent fuel pool issues in the licensing proceeding while its petition for rulemaking was pending concerning the same issue. Massachusetts v. United States, 522 F.3d 115, 118 (1st Cir. 2008). However, the First Circuit said it would "bind the NRC to its litigation position," id., whereby NRC said that Massachusetts could participate in the licensing proceeding as an "interested state" under 10 C.F.R. § 2.315(c) and may request, under 10 C.F.R. § 2.802(d), the Commission to suspend all or any part of any licensing proceeding to which the petitioner is a party pending disposition of the petition for rulemaking. Id. at 128. Subsequently, Massachusetts joined this proceeding as an interested state. Order (Commonwealth of Massachusetts Participation as Interested State) (May 12, 2008) (unpublished). As we understood it, the purpose of obtaining "interested state" status was so that Massachusetts could request a suspension of the license renewal proceeding under 10 C.F.R. § 2.802(d). See Massachusetts, 522 F.3d at 130; Entergy Nuclear Generation Co. and Entergy Nuclear Operations, Inc. (Pilgrim Nuclear Power Station), CLI-08-9, 67 NRC 353, 355 (2008). However, Massachusetts has not requested a suspension and on October 3, 2008, its counsel withdrew from this proceeding. Notice of Withdrawal of Appearance by Diane Curran (Oct. 3, 2008).

FEIS on August 1, 2007, and the FSER on February 25, 2008.[14] This triggered a cascade of filings and events leading to the evidentiary hearing. On April 28, 2008, NEC (on behalf of itself and Vermont) filed its initial statement of position, prefiled written testimony, and exhibits for all three contentions.[15] On May 13, 2008, Entergy and the NRC Staff filed their initial statements of position, prefiled written testimony, and exhibits.[16] In June the parties filed their rebuttal statements, written testimony, and exhibits.[17]

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[14] Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants Regarding Vermont Yankee Nuclear Power Station, NUREG-1437 (Supp. 30 Aug. 2007) [FEIS]; Safety Evaluation Report Related to the License Renewal of Vermont Yankee Nuclear Power Station, Docket No. 50-271, NUREG-1907 (issued Feb. 2008, bound version dated May 2008) [FSER].

[15] [NEC] Initial Statement of Position (Apr. 28, 2008) [NEC Initial Statement]; NEC Exh. NEC-JH_01, Pre-Filed Direct Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3 and 4 (Apr. 18, 2008) [Hopenfeld Decl.]; NEC Exh. NEC-RH_01, Pre-Filed Direct Testimony of Dr. Rudolf Hausler Regarding NEC Contention 4 (Apr. 22, 2006) [Hausler Decl.]; NEC Exh. NEC-UW_01, Pre-Filed Direct Testimony of Ulrich Witte Regarding NEC Contention 4 (Apr. 23, 2008) [Witte Decl.]; NEC Exhibits NEC-JH_02 to NEC-JH_62, NEC-RH_02 to NEC-RH_03, and NEC-UW_02 to NEC-UW_22.

[16] Entergy's Initial Statement of Position on [NEC] Contentions (May 13, 2008) [Entergy Initial Statement]; Entergy Exh. E2-01,Joint Declaration of James C. Fitzpatrick and Gary L. Stevens on NEC Contention 2A/2B – Environmentally Assisted Fatigue (May 12, 2008) [Fitzpatrick/Stevens Decl.]; Entergy Exh. E3-01, Joint Declaration of John R. Hoffman and Larry D. Lukens on NEC Contention 3 – Steam Dryer (May 9, 2008) [Hoffman/Lukens Decl.]; Entergy Exh. E4-01, Joint Declaration of Jeffrey S. Horowitz and James C. Fitzpatrick on NEC Contention 4 – Flow-Accelerated Corrosion (May 12, 2008) [Horowitz/Fitzpatrick Decl.]; Entergy Exhibits E2-02 to E2-37, E3-02 to E3-16, and E4-02 to E4-42; NRC Staff Initial Statement of Position on NEC Contentions 2A, 2B, 3, and 4 (May 13, 2008) [Staff Initial Statement]; NRC Staff Exh. 2, Affidavit of Kenneth C. Chang Concerning NEC Contentions 2A & 2B (Metal Fatigue) (May 12, 2008) [Chang Decl.]; NRC Staff Exh. 3, Affidavit of John R. Fair Concerning NEC Contentions 2A & 2B (Metal Fatigue) (May 13, 2008) [Fair Decl.]; NRC Staff Exh. 4, Affidavit of Kaihwa R. Hsu, Jonathan G. Rowley, and Thomas G. Scarbrough Concerning NEC Contention 3 (Steam Dryer) (May 13, 2008) [Hsu/Rowley/Scarbrough Decl.]; NRC Staff Exh. 5, Affidavit of Kaihwa R. Hsu and Jonathan G. Rowley Concerning NEC Contention 4 (Flow-Accelerated Corrosion) (May 13, 2008) [Hsu/Rowley Decl.]; Staff Exhibits 1, 6-23.

[17] NEC Rebuttal Statement of Position (June 2, 2008) [NEC Rebuttal Statement]; NEC Exh. NEC-JH_63, Pre-Filed Rebuttal Testimony of Dr. Joram Hopenfeld Regarding NEC Contentions 2A, 2B, 3 and 4 (June 2, 2008) [Hopenfeld Rebuttal Decl.]; NEC Exh. NEC-RH_04, Pre-Filed Rebuttal Testimony of Dr. Rudolf Hausler Regarding NEC Contention 4 (May 28, 2008) [Hausler Rebuttal Decl.]; NEC Exh. NEC-UW_23, Declaration of Ulrich Witte (June 6, 2008) [Witte Rebuttal Decl.]; NEC Exhibits NEC-JH_63 to NEC-JH_72, NEC-RH_04 to NEC-RH_05, and NEC-UW_24 to NEC-UW_26; Entergy's Supplemental Statement of Position on [NEC]

Thereafter, pursuant to our scheduling orders, the parties filed several motions in limine and motions to strike certain portions of the prefiled testimony and exhibits.[18] On July 16, 2008, the Board issued an order ruling on all of those motions.[19]

Meanwhile, after reviewing the initial and rebuttal statements of position, written testimony, and exhibits, the Board recognized that they presented certain legal issues that could benefit from briefing. The Board raised this point in a June 24, 2008, prehearing conference with the parties. Tr. at 672–77. On June 27, 2008, the Board issued an order requesting that the parties brief two main issues.[20] The first issue related to Contentions 2A and 2B and concerned the timing of the performance and submission of time-limited aging analyses (TLAAs) under 10 C.F.R. §§ 54.21(c) and 54.29. Id. at 3. This legal issue is discussed in Section III below. The second issue related to Contention 4 and concerned the level of information that an aging management program (AMP) must contain in order to satisfy the legal requirements of 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii). Id. at 5. This issue is discussed in Section V below.

Contentions 2A/2B (June 2, 2008) [Entergy Rebuttal Statement]; Joint Supplemental Declaration of James C. Fitzpatrick and Gary L. Stevens on NEC Contention 2A/2B – Environmentally Assisted Fatigue (May 30, 2008) [Fitzpatrick/Stevens Rebuttal Decl.]; NRC Staff Rebuttal Testimony Concerning NEC Contention 4 (June 2, 2008); NRC Staff Rebuttal Testimony of Kaihwa R. Hsu Concerning NEC Contention 4 (June 2, 2008) [Hsu Rebuttal Decl.]; Staff Exhibits A-D.

[18] Entergy's Motion in Limine (June 12, 2008) [Entergy Motion 1]; NRC Staff's Motion in Limine to Strike Testimony and Exhibits Filed by [NEC] (June 12, 2008) [Staff Motion 1]; [NEC] Motion to Strike NRC Staff Rebuttal Testimony Concerning NEC Contention 4 (June 12, 2008) [NEC Motion to Strike]; Entergy's Motion in Limine to Exclude the Rebuttal Testimony of Ulrich Witte (June 23, 2008) [Entergy Motion 2]; NRC Staff's Motion in Limine to Strike Late-Filed Rebuttal Testimony and Exhibits of NEC Witness Ulrich Witte (June 23, 2008) [Staff Motion 2].

[19] Order (Rulings on Motions to Strike and Motions in Limine) (July 16, 2008) (unpublished) [MIL Order].

[20] Order (Regarding the Briefing of Certain Legal Issues) (June 27, 2008) (unpublished) [Briefing Order].

II. GENERAL LEGAL STANDARDS APPLICABLE TO LICENSE RENEWALS

An application to renew the operating license of a commercial nuclear power plant may be granted only if the Commission finds that the continued operation of the facility "will be in accord with the common defense and security and will provide adequate protection to the health and safety of the public." 42 U.S.C. § 2232(a). The regulations implementing this statutory requirement are set out in 10 C.F.R. Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants."[21]

When the license renewal regulations were issued, the Commission acknowledged that the NRC's "ongoing processes" for regulating a nuclear power plant during its initial 40-year operating life "have not . . . addressed safety questions which, by their nature, become important principally during the period of extended operation beyond the initial 40-year license term."[22] Thus, the Commission concluded that analysis and management of "age-related degradation . . . must be elevated [sic] before a renewed license is issued. . . . [and] will be critical to safety during the term of the renewed license." Id. License renewal was not limited to age-related degradation however, because the Commission noted that "there may be other safety issues that may arise in connection with renewal that . . . are not relevant to safety during the initial operating license term . . . but, because of their plant-specific nature, must be addressed in renewals case by case." Id. The Commission added that "the licensing basis for a nuclear power plant during the renewal term will consist of the current licensing basis [CLB] and

[21] The NRC must also comply with the National Environmental Policy Act, 42 U.S.C. §§ 4321-4347 (NEPA) when evaluating a license renewal application. NRC's NEPA regulations are set out at 10 C.F.R. Part 51. The NEPA regulations addressing license renewal include 10 C.F.R. §§ 51.45(c), 51.53(c), 51.71(d), 51.95(c), and Part 51, Subpart A, Appendix B-1. Although several NEPA contentions were raised at the outset of this adjudicatory proceeding, no NEPA contentions survived to be heard at the July 2008 evidentiary hearing. The three contentions in this proceeding are founded on the Atomic Energy Act (AEA) section 182 (42 U.S.C. § 2232(a)) and 10 C.F.R. Part 54.

[22] Final Rule, Nuclear Power Plant License Renewal, 56 Fed. Reg. 64,943, 64,946 (Dec. 13, 1991).

new commitments to monitor, manage and correct age-related degradation unique to license renewal." Id. The term "current licensing basis" or CLB is a "term of art comprehending the various Commission requirements applicable to a specific plant that are in effect at the time of the license renewal application." Turkey Point, CLI-01-17, 54 NRC at 9. "CLB" is defined at 10 C.F.R. § 54.3(a) and "represents an 'evolving set of requirements and commitments for a specific plant that are modified as necessary over the life of a plant to ensure continuation of an adequate level of safety.'"[23]

The NRC Staff's review of the "safety" related aspects of each license renewal application focuses on two main issues – the adequacy of the applicant's AMPs and an evaluation of the applicant's TLAAs.[24] The scope of each license renewal proceeding "encompasses 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."[25]

Accordingly, in license renewal cases, the NRC Staff's safety evaluation reports in license renewal cases are divided into two main sections: "Aging Management Review Results" and "Time-Limited Aging Analyses." See FSER sections 3 and 4. "The license renewal review is intended to identify any additional actions that will be needed to maintain the functionality of the systems, structures and components in the period of extended operation." 60 Fed. Reg. at 22,464.

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[23] Id. at 9 (quoting Final Rule, Nuclear Power Plant License Renewal; Revisions, 60 Fed. Reg. 22,461, 22,473 (May 8, 1995)).

[24] TLAAs are defined in 10 C.F.R. § 54.3 as license calculations and analyses that: (1) involve systems, structures, and components (SSCs) within the scope of a license renewal, (2) consider the effects of aging, (3) involve time-limited assumptions defined by the current operating term, (4) are relevant to safety, (5) involve conclusions or provide the basis for conclusions related to the capability of the SSC to perform its intended function, and (6) are contained or incorporated by reference in the CLB.

[25] 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).

The regulations dealing with AMPs and TLAAs are found at 10 C.F.R. §§ 54.21 and 54.29. Adequate AMPs are both a required element of the license renewal application and a central finding that NRC must make before it can issue a license renewal. "Each application must . . . demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB for the period of extended operation." 10 C.F.R. § 54.21(a)(3).

Likewise, adequate TLAAs are a required component of the license renewal application and a necessary prerequisite to license renewal. "Each application must contain . . . [a]n evaluation of time-limited aging analyses." 10 C.F.R. § 54.21(c). With regard to each TLAA, the application must "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." 10 C.F.R. § 54.21(c)(1)(i)-(iii).

Both AMPs and TLAA's are subject to the requirement that the Commission may not grant a license renewal unless it finds that

> [a]ctions . . . have been or will be taken with respect to [the AMP or TLAA] such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB and that any changes made to the plant's CLB in order to comply with this paragraph are in accord with the Act and the Commission's regulations.

10 C.F.R. § 54.29(a).

Of the contentions admitted for litigation in this proceeding, Contentions 2A and 2B are TLAA contentions, challenging the adequacy of Entergy's TLAAs for metal fatigue, whereas Contentions 3 and 4 are AMP contentions, challenging the adequacy of Entergy's AMPs for aging of the steam dryer and flow accelerated corrosion, respectively. See Entergy Initial Statement of Position at 4. In each instance, the Board must find, inter alia, that Entergy has met the "reasonable assurance" standard of 10 C.F.R. § 54.29(a). The phrase "reasonable

assurance" is not defined,[26] but requires, at a minimum, that Entergy demonstrate compliance with all of NRC's safety regulations.[27] "[T]he sine qua non of adequate protection to public health and safety is compliance with all applicable safety rules and regulations." Maine Yankee, ALAB-161, 6 AEC at 1009. Entergy has the burden of proving that it has met the reasonable assurance standard by a preponderance of the evidence.[28]

While compliance with NRC regulations is legally mandatory, compliance with NRC guidance documents is neither necessary, nor necessarily sufficient, to satisfy the legal requirements that each application must meet under the AEA and Part 54.[29] For example, NRC guidance documents that play an important part in license renewals, such as NUREG-1800, Rev. 1 "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (Sept. 2005), and NUREG-1801, the "Generic Aging Lessons Learned (GALL) Report" (Sept. 2005), expressly acknowledge that they are not legally binding. "Legally binding

[26] A finding of "reasonable assurance that there will be adequate protection to the health and safety of the public" is based on judgment, not on the application of a mechanical verbal formula, a set of objective standards, or specific confidence interval. See Union of Concerned Scientists v. NRC, 880 F.2d 552, 558 (D.C. Cir. 1989) (explaining that "adequate protection" may be given content through case-by-case applications of technical judgment and that Congress neither defined, nor mandated that the Commission define, the term "adequate protection"). See also Revision of Backfitting Process for Power Reactors, 53 Fed. Reg. 20,603, 20,605 n.3 (June 6, 1988) (explaining that like "adequate protection," the phrase "reasonable assurance" is a determination that the NRC bases upon full consideration of all relevant information).

[27] Maine Yankee Atomic Power Co. (Maine Yankee Atomic Power Station), ALAB-161, 6 AEC 1003, 1009 (1973). See also AmerGen Energy Co., LLC (Oyster Creek Nuclear Generating Station), LBP-07-17, 66 NRC 327, 340 (2007).

[28] 10 C.F.R. § 2.325; Oyster Creek, LBP-07-17, 66 NRC at 340 (citing Commonwealth Edison Co. (Zion Station, Units 1 and 2), ALAB-616, 12 NRC 419, 421 (1980)). See also Consolidated Edison Co. of New York, Inc. (Indian Point Nuclear Generating Station, Unit 3), CLI-75-14, 2 NRC 835, 839 n.8 (1975).

[29] See Int'l Uranium (USA) Corp. (Request for Materials License Amendment), CLI-00-1, 51 NRC 9, 19 (2000) (NUREGs and Regulatory Guides "are routine agency policy pronouncements that do not carry the binding effect of regulations."); Curators of the University of Missouri, CLI-95-1, 41 NRC 71, 98 (1995) ("[I]t is well established . . . that NUREGs and Regulatory Guides, by their very nature, serve merely as guidance and cannot prescribe requirements.").

regulatory requirements are stated only in laws; NRC regulations; licenses, including technical specifications; or orders, not in the NUREG series publications."[30] Thus, although the parties have presented extensive evidence regarding Entergy's alleged compliance or non-compliance with various guidance documents related to the three contentions, compliance or non-compliance with such guidance, even if proven, is simply evidence and does not relieve this Board of the duty to determine whether Entergy has satisfied the relevant legal and regulatory requirements.

It is also important to note that the license renewal process is not meant to duplicate ongoing programs that review safety at operating reactors. Turkey Point, CLI-01-17, 54 NRC at 7. In promulgating the Part 54 regulations, the Commission stated specifically that it did not intend for license renewal to include a full assessment of all regulations affecting a plant's current operation. 56 Fed. Reg. at 64,945. In so stating, the Commission concluded that the NRC's "program of oversight is sufficiently broad and rigorous to establish that the added discipline of a formal license renewal review against the full range of current safety requirements would not add significantly to safety." Id. However, the CLB for the plant during the license renewal term is presumed to incorporate the CLB for the current license, including all licensee commitments, plus any "new commitments to monitor, manage, and correct age-related degradation unique to license renewal." Id. at 64,946.

[30] Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, NUREG-1800 (Rev. 1 Sept. 2005) at unnumbered introductory page 2 titled "Availability of Reference Materials in NRC Publications" [NUREG-1800 or SRP-LR]; Generic Aging Lessons Learned (GALL) Report, NUREG-1801, Vol. 1 (Rev. 1 Sept. 2005) at unnumbered introductory page 2 titled "Availability of Reference Materials in NRC Publications" [NUREG-1801 or GALL Report].

III. CONTENTIONS 2A AND 2B

A. Specific Background

1. Specific Procedural History

As will be discussed more fully below, Contentions 2A and 2B, which deal with the effects of metal fatigue on reactor components, are TLAA contentions that have evolved from an original AMP contention. The original contention (Contention 2) challenged the adequacy of Entergy's AMP for metal fatigue. Later, Entergy amended its LRA and, in response, NEC filed Contentions 2A and 2B, challenging the adequacy of Entergy's TLAA calculations concerning metal fatigue. Contentions 2A and 2B were admitted and Contention 2 was placed in abeyance. This partial initial decision does not deal with the original Contentions 2.

When this proceeding started, Entergy's LRA included calculations and analyses indicating that, if the VYNPS operated for an extra 20 years, then metal fatigue, i.e., "cumulative usage factor" (CUF), would exceed the regulatory limits for seven of the nine critical locations. LRA at 4.3-1, 4.3-6, and Table 4.3-3. The calculations included an "environmental adjustment factor" (Fen) to produce what is referred to as an "environmentally adjusted cumulative usage factor" or "CUFen" value.[31] The CUFen analyses are "time-limited aging analyses" within the meaning of 10 C.F.R. § 54.3(a). The CUFen TLAAs in Entergy's original LRA are referred to herein as the "Initial CUFen Analyses."

Given the fact that the Initial CUFen Analyses generated metal fatigue values that exceeded regulatory limits, the LRA was required to include a program to manage metal fatigue (i.e., an AMP). The AMP stated that Entergy would manage metal fatigue during the 20-year period of extended operation (PEO) by implementing one of three options: (1) further refinement of the fatigue analyses, (2) management of fatigue at affected locations, or (3) repair or replacement of affected locations. LRA at 4.3-7; LBP-06-20, 64 NRC at 184.

[31] Section III.B.1 herein more fully explains the concept of CUFens.

NEC's original "Contention 2" challenged the adequacy of the AMP, asserting that it was vague and incomplete, and was nothing more than a "plan to develop a plan." The Board admitted Contention 2 on the ground that it raised a genuine issue as to whether Entergy's AMP "demonstrate[d] that the effects of aging will be adequately managed" as required by 10 C.F.R. § 54.21(a)(3).[32]

Thereafter, Entergy redid its metal fatigue calculations for the nine key locations. On August 2, 2007, Entergy issued the results of these refined calculations, referred to herein as the "CUFen Reanalyses." LBP-07-15, 66 NRC at 263. The CUFen Reanalyses indicated that metal fatigue at the nine locations would not exceed regulatory limits and thus that an AMP was not required under 10 C.F.R. § 54.21(c)(1)(iii).

On September 4, 2007, NEC filed a motion to file a timely new or amended contention, challenging Entergy's CUFen Reanalyses and claiming that these TLAAs were flawed and failed to meet the requirements of 10 C.F.R. § 54.21(c).[33] On November 7, 2007, the Board admitted this new contention, denominating it "Contention 2A." LBP-07-15, 66 NRC at 267. Contention 2A, as admitted, reads as follows:

> The analytical methods 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.

Id. at 265-66.

When we admitted Contention 2A we recognized that it was qualitatively different from Contention 2. Contention 2 challenged the AMP, whereas Contention 2A challenged the TLAA.

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[32] LBP-06-20, 64 NRC at 186. Original Contention 2 reads as follows: "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, pursuant to 10 C.F.R. § 54.21(c)." Id. at 183.

[33] See [NEC]'s Motion to File a Timely New or Amended Contention (Sept. 4, 2007).

We recognized that "if Contention 2A is successful and Entergy's revised CUF analyses are not shown to be sufficient, then Entergy might return to relying on a fatigue management program as a way of satisfying the Part 54 regulations." Id. at 269. Under this scenario, Contention 2 would spring back to life. Accordingly, we expressly retained Contention 2 and held it in abeyance. Id.

As Contention 2A was being admitted, the NRC Staff also raised certain issues with regard to the CUFen Reanalyses. Specifically, the Staff was concerned that the simplified "Green's function"[34] methodology that Entergy used for the CUFen Reanalyses for three reactor locations (the feedwater, core spray and recirculation nozzles) might not be a conservative method of calculating stress loads during plant transient operations.[35] On this basis, the NRC Staff rejected Entergy's CUFen Reanalysis for the feedwater, core spray, and recirculation nozzles.[36] In light of this situation, Entergy agreed to perform a confirmatory CUFen analysis, without using the simplified Green's function methodology, on one of the three nozzles, the feedwater nozzle, which was thought to be bounding. Id. at 4-40 to 4-41. This new TLAA of the feedwater nozzle is referred to herein as the "Confirmatory CUFen Analysis."

Entergy provided the Confirmatory CUFen Analysis to NEC on February 15, 2008, and NEC promptly filed a motion to amend Contention 2A to challenge this new TLAA.[37] NEC asserted that the Confirmatory CUFen Analysis did not validate the results of the CUFen Reanalyses on the grounds that it only addressed one of many deficiencies in the CUFen

[34] The Green's function issue was also inherent in Contention 2A. It is explained more fully at III.3.B.h.

[35] Fitzpatrick/Stevens Decl. Post Tr. 763, at 18-20; Tr. at 925-27 (Stevens).

[36] FSER, Staff Exh-01 at 4-40 ("The staff finds there is not enough information to assure the validity of the Green's function . . . input.").

[37] [NEC] Motion to File a Timely New or Amended Contention (Mar. 17, 2008).

Reanalyses and only addressed the feedwater nozzle, which, in its view, is not bounding for the other components. Id. at 3.

On April 24, 2008, the Board admitted NEC's new or amended contention, which we deemed to be a subset of Contention 2A.[38] We noted that Contention 2A was still on the table and that the new contention, which we designated as Contention 2B, was simply "designed to prevent NEC from being foreclosed from challenging" the Confirmatory CUFen Analysis. Id.

Thus, after the admission of Contention 2B, the preparations for the evidentiary hearing focused on Contentions 2A and 2B, both of which challenged the adequacy of Entergy's TLAAs. See Entergy Initial Statement at 4. If the TLAAs were found to be adequate and predicted that metal fatigue during the 20-year PEO would stay within regulatory limits, then the adjudicatory proceeding would be closed. If the TLAAs were found to be inadequate, or predicted metal fatigue in excess of regulatory limits during the PEO, then the original Contention 2, dealing with the adequacy of Entergy's AMP for metal fatigue, would re-surface.

The final significant point in the procedural history of Contentions 2A/B deals with the question of the timing of performing certain additional and necessary CUFen analyses, namely the reanalyses of the core spray (CS) and the reactor recirculation (RR) nozzles, the other two nozzles affected by the use of the simplified Green's function methodology. Even after the Confirmatory CUFen Analysis for the feedwater (FW) nozzle, the NRC Staff remained concerned about the CS and RR nozzles. See FSER at 4-43. Entergy sought to allay these concerns via its "Commitment 27" whereby it promised to "refine our current fatigue analyses to include the effects of reactor water environment and verify that the cumulative usage factors (CUFs) are less than 1." Id. at A-8.

Based on this approach, the NRC Staff approved Entergy's license renewal. But the Staff's approval was expressly conditioned on Entergy's Commitment 27 whereby it promised that, after the license was issued, it would perform confirmatory CUFen analyses on the core

[38] Order (Granting Motion to Amend NEC Contention 2A) (Apr. 24, 2008) at 2 (unpublished).

spray and the reactor recirculation nozzles. Specifically, the Staff included a proposed license condition (Condition 4) on this subject:

> The fourth license condition requires that the licensee perform and submit to the NRC for review and approval, a ASME Code analysis for the reactor recirculation outlet nozzle and the core spray nozzle at least two years prior to the period of extended operation. These analyses should be documented in the FSAR as the analysis-of-record for these two nozzles.

Id. at 1-12.

The difficulty with the NRC Staff's FSER position is that it rejected the same approach six months earlier. In August 2007, the Staff rejected proposed Commitment 27 on the ground that the confirmatory CUFen analyses for the core spray and reactor recirculation nozzles must be completed before the license renewal could be issued. At that time the Staff stated:

> It is the NRC position that in order to meet the requirements of 10 C.F.R. § 54.21(c)(1), an applicant for license renewal must demonstrate in the LRA that the evaluation of time-limited aging analyses (TLAA) has been completed. The NRC does not accept a commitment to complete the evaluation of TLAA prior to the period of extended operation.[39]

NEC raised this issue as a part of its pre-hearing filings, arguing, inter alia, that if Entergy were permitted to postpone performing the necessary metal fatigue CUFen analyses until after the license renewal was issued, it "would defeat NEC's due process rights in this proceeding and deny public review of Entergy's TLAA," NEC Initial Statement at 19, would be "inconsistent with [the] plain [regulatory] language and with standard rules of construction," would render 10 C.F.R. § 54.21(c)(1)(ii) "mere surplusage," and would "frustrate public scrutiny of the TLAA methodology." NEC Rebuttal Statement at 4-6.

On June 27, 2008, the Board instructed the parties to brief the following issues:

> Issue 1A: Does a license condition that requires the performance of certain CUFen TLAAs after the license renewal is issued comply with the law,

[39] NEC Exh. NEC-JH_62 at enclosure 2, NRC Summary of Telephone Conference Call Held August 20, 2007, Between the U.S. Nuclear Regulatory Commission and Entergy Nuclear Operations, Inc., Concerning the Vermont Yankee Nuclear Power Station License Renewal Application (Oct. 25, 2007).

particularly Part 54 and the requirement that the license application "contain . . . an evaluation of time-limited aging analyses" pursuant to 10 C.F.R. § 54.21(c)?

Issue 1B: Is it legally permissible under 10 C.F.R. § 54.29 to issue a license renewal even though certain of the TLAAs have not been performed?[40]

The parties submitted initial briefs on these issues on July 9, 2008 and responsive briefs on July 15, 2008. We address these issues at Section III.C.1 below.

2. Specific Legal Standards and Issues Applicable to TLAAs

The primary legal standard that applies to Contentions 2A and 2B reads as follows:

> Each application must contain the following information: . . .
> (c) An evaluation of the 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.

10 C.F.R. § 54.21(c).

In short, each license renewal application must contain three things, (1) an evaluation of TLAAs, (2) a list of TLAAs, and (3) a demonstration relating to TLAAs. But the regulation fails to specify what is meant by the first requirement. There is no guidance as to what the "evaluation" must cover or contain. But, since one cannot evaluate a TLAA unless the TLAA exists, the evaluation requirement seems to presume the pre-existence of the TLAAs.

Likewise, the regulation does not specify clearly what will satisfy the third requirement, i.e., that the application contain a "demonstration." Under 10 C.F.R. § 54.21(c)(1)(i)-(iii), the applicant has three options for meeting the demonstration requirement. With regard to option (i), the regulation calls for a demonstration that the TLAAs "remain valid" for the PEO. There is no definition of what this means. An analysis might be deemed "valid" if it is performed in a technically accurate manner and covers the entire PEO. But it is clear that a technically

[40] Order (Regarding the Briefing of Certain Legal Issues) (June 27, 2008) at 3 (unpublished).

accurate TLAA that shows that the component will fail during the PEO is not enough to satisfy 10 C.F.R. § 54.21(c)(1)(i).

Similarly, when 10 C.F.R. § 54.21(c)(1)(ii) asks for a demonstration that the TLAA has "been projected to the end of the PEO," a technically accurate projection of the TLAA that predicts that the component will fail due to aging during the 20-year PEO will not suffice. It is clear that the subsection (i) and (ii) "demonstrations" require that the TLAA both (1) be performed in a technically accurate manner, and (2) produce a prediction that the component will not fail due to aging during the PEO.

The litigation concerning Contentions 2A and 2B focused on subsection 54.21(c)(1)(ii), presenting opposing evidence as to whether Entergy's TLAA "projections" (i.e., the CUFen Reanalyses and Confirmatory CUFen Analyses) were performed in a technically accurate manner and whether the results of these TLAAs are adequate and provide reasonable assurance that the reactor component will not fail due to metal fatigue during the PEO.

The third way an applicant can make the required demonstration under 54.21(c)(1)(i)-(iii) must be read in the context of the first two. Under options (i) and (ii) the applicant can demonstrate compliance by performing calculations that predict the component in question will not fail, due to aging, during the PEO. In contrast, option (iii) allows the applicant to pursue a license renewal even if the TLAAs predict that the component will fail during the PEO. In such a situation, a license renewal can still be granted if the applicant demonstrates that the effects of aging will be adequately managed during the PEO, i.e., the applicant demonstrates that it has an AMP and that the AMP is adequate. Under 10 C.F.R. § 54.21(c)(1)(iii), the applicant can use an AMP either when (1) the TLAAs predict that the component in question will fail due to aging during the PEO or (2) the applicant foregoes the TLAAs and assumes that aging is a problem. 60 Fed. Reg. at 22,480.

As we discuss in Section III.C below, 10 C.F.R. § 54.21(c)(1)(i)-(iii) requires that the applicant make its demonstration in the application, which is necessarily before the license may

be granted. The applicant has a choice: either perform an analysis-of-record that demonstrates that aging is not a problem, or demonstrate that it will manage aging, i.e., TLAA or AMP. The demonstration is a condition precedent to issuance of a license renewal. Section 54.21(c)(1) does not allow the applicant to postpone the demonstration and say: renew our license now, and we will do our predictive TLAA (analysis-of-record) later to determine whether an AMP is needed.

3. Evidentiary Record

a. Identification of Witnesses

The parties proposed a total of six witnesses to provide fact and/or opinion testimony with regard to Contentions 2A and 2B. However one of NEC's witnesses, Mr. Ulrich K. Witte, was found not to be qualified to provide expert opinion on the points covered in his proffered testimony on Contentions 2A and 2B. MIL Order at 8. Therefore, his prefiled written testimony was stricken and Mr. Witte did not testify regarding these contentions. Id. In addition, one of the NRC Staff's witnesses, Dr. Kenneth C. Chang, was unable to testify at the evidentiary hearing due to medical conditions. Tr. at 720-22. The remaining four individuals testified in person at the evidentiary hearing and were found to be qualified to present their testimony on the matters they addressed.

Entergy presented two witnesses – Mr. James C. Fitzpatrick and Mr. Gary L. Stevens – who testified concerning Contentions 2A and 2B. On May 12, 2008, Entergy submitted its joint direct declaration for Mr. Fitzpatrick and Mr. Stevens, which was later submitted as an exhibit. Fitzpatrick/Stevens Decl. The Fitzpatrick/Stevens Decl. was later corrected, admitted into evidence, and incorporated into the transcript as if read. Tr. at 763. On May 30, 2008, Entergy submitted the joint rebuttal declaration of Mr. Fitzpatrick and Mr. Stevens, which was later submitted as an exhibit. Fitzpatrick/Stevens Rebuttal Decl. The Fitzpatrick/Stevens Rebuttal

Decl. was later corrected, admitted into evidence, and incorporated into the transcript as if read.[41] Tr. at 763.

Mr. Fitzpatrick is a registered professional engineer and has both a Bachelor of Science degree and a Masters of Science degree in civil engineering from Northeastern University. He has 30 years of technical and supervisory experience working in the nuclear industry, including a long stint working at or on the VYNPS (1986-2008) culminating as Entergy's "Senior Lead Engineer, Design Engineering."[42] In this capacity, Mr. Fitzpatrick provided support to Entergy with regard to metal fatigue and flow accelerated corrosion. Id. He currently works for AREVA, NP, another company in the nuclear industry. Id.

Mr. Stevens is a registered professional engineer and has a Bachelor of Science degree in mechanical engineering from San Jose State University and a Masters of Science degree in mechanical engineering from California Polytechnic State University.[43] He has technical and supervisory experience working for the nuclear industry, including 14 years at GE Nuclear Energy (1981-1995) and 13 years with Structural Integrity Associates, Inc. (SIA), where he is currently employed. Id. Entergy retained SIA to perform the CUFen Reanalyses and Confirmatory CUFen Analyses and Mr. Stevens supervised the performance of these calculations. Fitzpatrick/Stevens Decl. Post Tr. 763, at 8 (Stevens).

The NRC Staff initially presented two of its employees as witnesses – Dr. Kenneth C. Chang and Mr. John R. Fair – on Contentions 2A and 2B. See Staff Initial Statement at 1. Dr.

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[41] The testimony contained in these two declarations, is cited herein as Fitzpatrick/Stevens Decl. Post Tr. 763, at xx (Fitzpatrick or Stevens) or Fitzpatrick/Stevens Rebuttal Decl. Post Tr. 763, at xx (Fitzpatrick or Stevens).

[42] Fitzpatrick/Stevens Decl. Post Tr. 763, at 1-2 (Fitzpatrick); Entergy Exh. E2-02, James C. Fitzpatrick Resume.

[43] Fitzpatrick/Stevens Decl. Post Tr. 763, at 7 (Stevens); Entergy Exh. E2-08, Gary L. Stevens Resume.

Chang was personally and substantially involved in the Staff's metal fatigue safety review of VYNPS, while Mr. Fair was not.

On May 12, 2008, the NRC Staff submitted an affidavit from Dr. Chang presenting testimony concerning the Staff's review of the metal fatigue issues at VYNPS.[44] This affidavit indicated that Dr. Chang was the NRC's Chief of Engineering Branch 1 in the Division of License Renewal of the Office of Nuclear Reactor Regulation (NRR) with "overall responsibility" for the safety review of AMPs and TLAAs relating to metal fatigue. Chang Decl. at 1. Dr. Chang asserted that he is a known expert in areas of metal fatigue and fatigue monitoring and the NRC Staff individual who personally reviewed Entergy's metal fatigue submissions and wrote Section 4.3.3 "Effects of Reactor Water Environment on Fatigue Life" of the FSER. Id. at 1-2.

Subsequently, Dr. Chang was unable to testify at the evidentiary hearing and the NRC Staff offered to withdraw his prefiled written affidavit. Tr. at 721 (Baty). NEC raised concerns, arguing that Dr. Chang, as the person who directed and led the Staff's metal fatigue review, was a crucial witness whose absence was problematic. Tr. at 722 (Tyler). The Board agreed that Dr. Chang was a key NRC Staff witness, but concluded that despite Dr. Chang's absence, the evidentiary hearing would proceed. Tr. at 1176. The Board admitted Dr. Chang's affidavit into evidence as an exhibit. Tr. at 1176.

As to the other NRC Staff witness, Mr. Fair's affidavit was also submitted by the Staff on May 13, 2008. Fair Decl. The Fair Decl. was corrected, admitted into evidence, and incorporated into the transcript as if read.[45] Tr. at 766-68.

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[44] Chang Decl. The NRC Staff submitted a letter correcting Dr. Chang's affidavit on May 22, 2008. Letter from Lloyd B. Subin, Counsel for NRC Staff, to Licensing Board (May 22, 2008). Both the May 13, 2008 affidavit and May 22, 2008 corrections were submitted as NRC Staff Exh. 2, Affidavit of Kenneth C. Chang Concerning NEC Contentions 2A & 2B (Metal Fatigue).

[45] This prefiled testimony is in the transcript and is cited herein as Fair Decl. Post Tr. 768, at xx.

Mr. Fair, although not specifically assigned to review Entergy's LRA for VYNPS and not involved in writing the FSER, possesses substantial experience (over 35 years) in the nuclear industry and significant expertise in fatigue evaluations and the ASME requirements.[46] In addition, Mr. Fair provided advice to the NRC Division of License Renewal concerning Entergy's LRA and provided support to the Staff during meetings with the NRC Advisory Committee on Reactor Safety (ACRS). Fair Decl. Post Tr. 768, at 1. Mr. Fair was also directly involved in preparation of an NRC regulatory issue summary that related to a problem (which arose in this case) in using the simplified Green's function methodology in calculating CUFens for metal fatigue.[47] Despite his lack of direct involvement in the VYNPS LRA and FSER, Mr. Fair's testimony was helpful to the Board.

On April 28, 2008, NEC submitted written direct testimony by Dr. Joram Hopenfeld in support of its position on Contentions 2A and 2B. Hopenfeld Decl. On June 2, 2008, NEC submitted written rebuttal testimony by Dr. Hopenfeld. Hopenfeld Rebuttal Decl. This prefiled testimony was admitted into evidence and incorporated into the transcript as if read.[48] Tr. at 778-79.[49]

Dr. Hopenfeld holds Bachelor of Science, Masters of Science, and Doctor of Philosophy degrees in mechanical engineering from the University of California at Los Angeles. He has 45 years of experience in industry and government, including 18 years with the NRC, primarily in

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[46] Fair Decl. Post Tr. 768, at 1-2; see also id. at John R. Fair Statement of Professional Qualifications.

[47] NEC Exh. NEC-JH_23, NRC Draft Regulatory Issue Summary 2008-10 Fatigue Analysis of Nuclear Power Plant Components (April 11, 2008) at 2 [Draft RIS].

[48] The testimony contained in these two declarations is cited herein as Hopenfeld Decl. Post Tr. 779, at xx or Hopenfeld Rebuttal Post Tr. 779, at xx.

[49] As previously stated, NEC also proffered certain prefiled written testimony of Mr. Ulrich Witte, but Entergy and the NRC Staff challenged Mr. Witte's expertise on the issues covered by his testimony, and the Board granted the motion to strike Mr. Witte's declarations. See MIL Order at 8.

the areas of thermal hydraulics, materials, corrosion, radioactivity transport, instrumentation, steam generator testing, and accident analysis. Hopenfeld Decl. Post Tr. 779, at 1.

In summary, the evidentiary record on Contentions 2A and 2B includes the prefiled and live testimony at the evidentiary hearing by four witnesses – Mr. Fitzpatrick, Mr. Stevens, Mr. Fair, and Dr. Hopenfeld – and prefiled written testimony from a fifth witnesses – Dr. Chang.

b. Relevant Staff Guidance Documents

The evidence related to Contentions 2A and 2B includes a number of guidance documents that have been issued by the NRC Staff. These guidelines reflect the Staff's interpretations on various subjects related to license renewal and metal fatigue, such as (1) how an applicant can satisfy the regulatory and legal requirements necessary to obtain a license renewal, and (2) how the Staff will undertake to ensure quality and uniformity in performing its review and evaluation of LRAs. Such guidance documents, as well as compliance or non-compliance with them, are part of the evidence to be weighed by the Board and are not legally binding or determinative. The guidance documents introduced as evidence herein, and most relevant to Contentions 2A and 2B are as follows:

1. NUREG-1800, Rev. 1, "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (Sept. 2005) (NRC Staff Exh. 19). This document provides guidance to the NRC Staff reviewers for performing safety reviews of LRAs under 10 C.F.R. Part 54. For example, section 4.3 of NUREG-1800 addresses "Metal Fatigue Analysis" TLAAs in the context of license renewals and is particularly relevant to Contentions 2A and 2B.

2. NUREG-1801, "Generic Aging Lessons Learned (GALL) Report" (Sept. 2005) (NRC Staff Exh. 7; Entergy Exh. E2-05.) (GALL Report). NUREG-1801 contains the Staff's generic evaluation of existing power plant programs and documents the NRC Staff's judgments as to where existing programs need to be augmented in order to protect the public during the period of extended operation covered in any license renewal. NUREG-1801 at 1. NUREG-1801 also articulates the NRC Staff guidance as to how applicants may perform TLAAs or demonstrate

that their AMPs will satisfy the Part 54 regulatory requirements. For example, section X.M1 of NUREG-1801 addresses "Metal Fatigue of Reactor Coolant Pressure Boundary" and lays out ten principles that the Staff believes ought to be reflected in a metal fatigue AMP.

3. NUREG/CR-5704 "Effects of LWR Coolant Environments on Fatigue Design Curves of Austenitic Stainless Steels (Apr. 1999) (NRC Staff Exh. 12; Entergy Exh. E2-07). NUREG/CR 5704 summarizes work done by an NRC contractor, Argonne National Laboratory (Argonne), on fatigue of austenitic stainless steels in simulated light water reactor (LWR) environments. It provides information and guidance as to how to adjust the ASME metal fatigue design curve calculations (i.e., the CUF) to reflect the effects associated with environmental conditions inside a LWR nuclear power plant (i.e., the Fen) so that the CUFen can be determined.

4. NUREG/CR-6583 "Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low-Alloy Steels" (Feb. 1998) (NRC Staff Exh. 11; Entergy Exh. E2-06). This guidance document is similar to NUREG/CR-5704, except that NUREG/CR-6583 summarizes work done by Argonne on fatigue of carbon and low-alloy steels in simulated LWR environments.

5. NUREG/CR-6909 "Effects of LWR Coolant Environments on the Fatigue Life of Reactor Materials" (Feb. 2007) (Entergy Exh. E2-30). NUREG/CR-6909 is another Argonne report that updates and reviews metal fatigue data for carbon and low-alloy steels and austenitic stainless steels both in air environments and LWR environments. It also provides a critical review of the ASME Code metal fatigue design margins and assesses the possible conservatisms in those design margins. NUREG/CR-6909 at xvi.

6. NUREG/CR-6260 "Application of NUREG/CR-5999 Interim Fatigue Curves to Selected Nuclear Power Plant Components" (Feb. 1995) (NRC Staff Exh. 6). This NUREG provides the results of studies of metal fatigue on various components and locations within a nuclear power plant. NUREG-1801 section X.M1 recommends that license renewal applicants

use the guidance in NUREG/CR-6260 to identify the critical components and locations and then apply the appropriate environmental life correction factors (Fen) from NUREG/CR-6583 or 5704.

7. Regulatory Guide 1.207 "Guidelines for Evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components Due to the Effects of the Light-Water Reactor Environment for New Reactors" (Mar. 2007) (NRC Staff Exh. 13) [RG-1.207]. This document provides guidance for use in determining the acceptable fatigue life of ASME pressure boundary components in LWR environments. RG-1.207 endorses the use of NUREG/CR-6909, including its method of calculating LWR environmental effects on metal fatigue (Fen), its new stainless steel air design curve, and its statistical method ("95/95 criterion") for assessing the fatigue design curves. When it issued this guidance however, the NRC Staff decided that it would only apply NUREG/CR-6909 to "new nuclear reactor construction permits or operating licenses." RG-1.207 at 2-3. The Staff opined that the newer data and methods did not need to be applied to metal fatigue analyses in the current fleet of reactors because of "conservatism in quantifying other plant-related variables." Id. at 2.

8. "Closeout of Generic Safety Issue 190, 'Fatigue Evaluation of Metal Components for 60-year Plant Life'" Memorandum by Ashok C. Thadoni (NRR) to William D. Travers (EDO) (Dec. 26, 1999) (Entergy Exh. E2-03) [GSI-190 Memo]. This guidance document reflects the Staff's conclusion that the effects of LWR environments (i.e., Fen) must be included in the calculation of metal fatigue when an applicant seeks a license renewal. "[T]he staff concludes that, consistent with existing requirements in 10 CFR 54.21, licensees should address the effects of the coolant environment on component fatigue life as aging management programs are formulated in support of license renewal." GSI-190 Memo at 1.

9. "NRC Regulatory Issue Summary 2008-10 Fatigue Analysis of Nuclear Power Plant Components," NRC Office of Nuclear Reactor Regulation (NRR) (Apr. 11, 2008) (NEC Exh. NEC-JH_23) [RIS-08-10]. The RIS-08-10 is an alert that NRC recently issued to the holders of all nuclear power plant licensees announcing NRC's "concern regarding the methodology used

by some license renewal applicants to demonstrate the ability of nuclear power plant components to withstand the cyclic loads associated with plant transient operations for the period of extended operation." RIS-08-10 at 2. The concern involved the use of a "simplified input for applying the Green's function in which only one value of stress is used for the evaluation of the actual plant transients. . . . [whereas] [t]he detailed stress analysis requires consideration of six stress components." Id. The NRC Staff indicates that the use of this simplified input to the Green's function "could be nonconservative if not correctly applied." Id. at 1. Therefore the Staff requested that all recent license renewal applicants that used this simplified Green's function methodology redo these analyses ("perform confirmatory analyses"). Id. at 2.

B. Findings of Fact

1. Basic Concepts and Definitions

Resolution of the issues raised by Contentions 2A and 2B (e.g., whether the analytical methods employed by Entergy's CUFen Reanalyses or Confirmatory CUFen Analyses were flawed, insufficiently conservative, and/or fail to demonstrate that the reactor components will not fail due to metal fatigue during the PEO) requires an overview of some of the basic and uncontested facts and concepts associated with metal fatigue, TLAAs, and the CUFens analytical methods.[50]

"Experience with operating nuclear plants worldwide reveals that many failures may be attributed to fatigue," such as metal fatigue. Entergy Exh. E2-06 at 2. Metal fatigue is an age related degradation mechanism caused by mechanical and thermal stresses on metal components. The results of metal fatigue can be observed in the cracking of components

[50] The "Technical Background" section of the Commission's recent decision in Oyster Creek provides a synopsis of the concepts of metal fatigue, CUF, CUFen, relevant regulations and Staff guidance, and the simplified Green's function methodology. Amergen Energy Company, LLC (License Renewal for Oyster Creek Nuclear Generating Station), CLI-08-28, 68 NRC __, __ (slip op. at 5-10) (Nov. 6, 2008).

subject to stress cycles of sufficient magnitude and duration.[51] During each stress or "loading cycle," some fraction of a component's fatigue life is consumed; the amount depends on the magnitude of the applied stress. Eventually, after a certain number of cycles or stresses, the component's total allowable fatigue life is fully expended. The component's CUF is a summation of individual usage factors. An individual usage factor is the number of actual cycles experienced for a particular stress level divided by the number of cycles at which failure is expected to occur for this stress level.[52]

Transients contribute to metal fatigue. A "transient" is a change in a nuclear reactor operating parameter, such as a change in temperature or pressure of the reactor coolant. Tr. at 822-26. Such changes can cause mechanical or thermal stress on a component and contribute to the consumption of that component's allowable metal fatigue life. Id. According to Entergy, as of July 23, 2008, 663 transients have occurred at VYNPS since it began operation.[53]

The source of the requirement to perform metal fatigue CUFs for reactor components is found in the regulations as follows. Appendix A to 10 C.F.R. Part 50 establishes "General Design Criteria [GDC] for Nuclear Power Plants." Appendix A – GDC 1 specifies that "[s]tructures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed." Appendix A – GDC 30 requires that components that are "part of the reactor coolant pressure boundary shall be designed, fabricated, erected and tested to the highest quality standards practical." Augmenting the GDCs is 10 C.F.R. § 50.55a "Codes and Standards," which endorses the use of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code in assessing metal fatigue. In particular, 10 C.F.R. §

[51] FSER at 4-22; NEC Exh. NEC-JH_03 at 1; Fitzpatrick/Stevens Decl. Post Tr. 763, at 2 (Fitzpatrick).

[52] NEC Exh. NEC-JH_03 at 1; Fitzpatrick/Stevens Decl. Post Tr. 763, at 3-4 (Fitzpatrick).

[53] Entergy Exh. E2-39, Vermont Yankee Transient Counting Status: July 23, 2008 (July 23, 2008).

50.55a(c) states that "[c]omponents which are part of the reactor coolant pressure boundary must meet the requirements for Class 1 components in Section III of the ASME Boiler and Pressure Vessel Code." See also NRC Staff Exh. 13 at 1.

The feedwater, reactor recirculation, and core spray nozzles on a BWR nuclear power reactor such as VYNPS are part of the "reactor coolant pressure boundary." They must be designed, fabricated, erected, and tested to the "highest quality standards practical," and must meet the Class I requirements of ASME BPV Code Section III. See Oyster Creek, CLI-08-28, 68 NRC at __ (slip op. at 5-6).

ASME Code Section III sets forth procedures for analyzing components for metal fatigue, provides "fatigue curves" for various materials, and requires that the CUF for any given location or Class I component not exceed 1.0 or "unity."[54] The ASME Code fatigue design curves and CUFs are based on fatigue testing of polished metal, at room temperature, in an air environment.[55] This is problematic because the actual environment inside of a nuclear reactor is very different. LWR environments such as the VYNPS involve non-polished metal, and water and steam at very high and changing temperatures and pressures, which shorten the life-span of metal components and can significantly increase metal fatigue beyond that predicted by the ASME (air/room temperature) fatigue curves.[56] "For components . . . exposed to reactor coolant water, the fatigue life, as measured by the allowable number of stress cycles, is reduced compared to the components' fatigue life when exposed to an air environment." Fitzpatrick/Stevens Decl. Post Tr. 763, at 4 (Fitzpatrick).

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[54] NEC Exh. NEC-JH_03 at 1-2; Fitzpatrick/Stevens Decl. Post Tr. 763, at 4 (Fitzpatrick).

[55] NRC Staff Exh. 13 at 2; NEC Exh. NEC-JH_03 at 2; Fitzpatrick/Stevens Decl. Post Tr. 763, at 4-5 (Fitzpatrick).

[56] See Entergy Exh. E2-06 at xiii ("Recent fatigue strain vs. life (S-N) data obtained in the U.S. and Japan demonstrate that light-water reactor (LWR) environments can have potentially significant effects on the fatigue resistance of materials. Specimen lives in simulated LWR environments can be much shorter than those for corresponding tests in air."); NUREG/CR-5704 at ix; NUREG/CR-6909 at iii and xv; Tr. at 951-53 (Stevens).

In order to account for the effects of the actual LWR coolant environment on metal fatigue, the ASME Code CUF factor (based on air, room temperature, and polished metal surfaces) is adjusted or multiplied by an environmental correction factor, or "Fen."[57] This results in an environmentally adjusted CUF, i.e., a CUFen. The resulting CUFen still must not exceed unity. Fitzpatrick/Stevens Decl. Post Tr. 763, at 6 (Fitzpatrick).

In recognition of this, the NRC Staff concluded that, due to the increased probability of problems at plants operating beyond their original 40-year license term, applicants for license renewal should address the effects of the LWR coolant environment (Fen) on metal fatigue (CUF). Fitzpatrick/Stevens Decl. Post Tr. 763, at 5 (Fitzpatrick). Therefore if a license renewal applicant seeks to demonstrate, per 10 C.F.R. § 54.21(c)(1)(ii), that its TLAA has been projected to the PEO, it must perform a CUFen calculation, not just a CUF calculation.[58] There are two types of applications or uses for CUFs and CUFens. One is a predictive mode and the other is a tracking or monitoring mode. Tr. at 1144-45 (Fair).

It is important to note that if and when a CUFen for a particular component exceeds unity, it does not necessarily mean that the component will fail at that moment. Tr. at 824-25 (Stevens); Tr. at 1130-31 (Hopenfeld). It merely means that the metal fatigue on that component has exceeded the ASME acceptance criterion. Tr. at 825, 838 (Stevens); Tr. at 1130 (Hopenfeld). For example, in NUREG/CR-6583 a CUF of unity means that there is a one to five percent probability that the component will experience a crack in the metal that is three millimeters deep. Tr. at 898, 900-01 (Fair). This is not necessarily a failure of the component. Tr. at 900-01 (Fair).

[57] NEC Exh. NEC-JH_03 at 1; Fitzpatrick/Stevens Decl. Post Tr. 763, at 5 (Fitzpatrick).

[58] See Fitzpatrick/Stevens Decl. Post Tr. 763, at 5 (Fitzpatrick); see also FSER at 4-32 to 4-33.

2. Joint Stipulations

Pursuant to the Board's instructions, Entergy, the NRC Staff, and NEC developed and submitted several joint stipulations with respect to Contentions 2A and 2B. These are as follows:

> 1. Section 4.3.3 of the License Renewal Application for VY ("Application") presents Entergy's initial assessment of the effects of the reactor coolant environment on fatigue life for nine plant-specific locations of six reactor components at VY selected in accordance NUREG/CR-6260 and the NRC Staff's "GALL Report" [Initial CUFen Analyses].
>
> 2. The initial CUFens computed by Entergy for VY are tabulated in Table 4.3.3 of the Application. As that Table shows, seven of the nine locations had CUFens greater than unity, and therefore greater than the specified criterion of the ASME code.
>
> 3. To address these results, the Application states (Application, Section 4.3.3 at 4.3-7) that, prior to entering the period of extended operation, for each location that may exceed a CUF of 1.0 when considering environmental effects, VY will implement one of three possible courses of action, including "further refinement of the fatigue analyses to lower the predicted CUFs to less than 1.0."
>
> 4. Entergy engaged SIA to perform refined analyses to calculate the CUFs, Fens, and CUFens for all nine locations of interest in accordance with the approach described in the GALL Report.
>
> 5. Final versions of fifteen refined calculations were issued in August and December 2007 [CUFen Reanalyses].
>
> 6. To resolve certain NRC Staff concerns, Entergy proposed, and the NRC Staff accepted, that Entergy perform a confirmatory CUFen analysis of the feedwater nozzle using methods that would be acceptable to the NRC [Confirmatory CUFen Analysis].
>
> 7. The Staff imposed a license condition requiring similar confirmatory analyses for two other nozzles, the recirculation outlet nozzle and the core spray nozzle. Those confirmatory analyses will become the "analyses of record" for those two locations. Entergy is to submit these analyses to the Staff no later than two years prior to the start of the period of extended operation, in March 2012.

Joint Stipulation (July 8, 2008) at unnumbered pages 1-2 [Joint Stipulation].

3. Factual Findings on Key Contested Matters

Having set forth the legal and regulatory requirements, procedural history, NRC Staff guidance, and basic factual framework relating to Contentions 2A and 2B, the Board now turns

to the key issues raised by these contentions. NEC alleges that, with regard to aging due to metal fatigue, Entergy's CUFen Reanalyses and Confirmatory CUFen Analyses fail to comply with the requirements of 10 C.F.R. § 54.21(c). The following are NEC's main allegations:

a. Outdated Equations: Entergy used "outdated" statistical equations in NUREG/CR-5704 and 6583, instead of the more recent equations in NUREG/CR-6909 to calculate the Fen factors. NEC Exh. NEC-JH_03 at 10-11.

b. Dissolved Oxygen: Entergy's Fen calculations do not adequately account for the dissolved oxygen (DO) chemistry of the LWR water. Id. at 16.

c. Base Metal Cracking: Entergy has not provided proof that the base metal cladding of the feedwater nozzle is not cracked. Id. at 15.

d. Surface Finish: Entergy's Fen calculations do not adequately account for the surface roughness of the components it evaluated. Id. at 11.

e. Number of Transients: The number of plant transients estimated to occur over the plant operating life and PEO is not appropriate and not sufficiently conservative. Id. at 16.

f. Lack of Error Analysis: "Entergy should have performed an error analysis to show the admissible range for each variable" in the CUFen analyses. Id. at 18.

g. Heat Transfer Equations: Entergy used inappropriate heat transfer equations and assumptions in calculating the Fen. Id. at 12.

h. Simplified Green's Function Methodology: Entergy's CUF calculations used the simplified Green's function methodology, resulting in inaccurate CUF and CUFen analyses. Id. at 17-18. The Confirmatory CUFen Analysis for the feedwater nozzle does not solve or bound the problem with regard to the core spray and reactor recirculation outlet nozzles. Id. at 18-19.

As a final note, in subsection (i) we review Dr. Hopenfeld's CUFen recalculations to see if they provide a better assessment of the metal fatigue at VYNPS.

Our factual findings on each of these contested issues are set forth in turn.

a. Outdated Equations

i. Evidence

NEC asserts that Entergy should have used the Fen parameters in NUREG/CR-6909 in its CUFen analyses because that NUREG is based on a larger database and its limits are more clearly stated than the Fen parameters in the older NUREG/CR-5704 and 6583. Id. at 10. NEC's expert, Dr. Hopenfeld, testified 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 Decl. Post Tr. 779, at 4. Dr. Hopenfeld, however, does not recommend the use of NUREG/CR-6909 air design curves because they have not been officially accepted by the ASME. Id. at 7. Dr. Hopenfeld argues that the CUFen analyses should use a hybrid combination – the Fen factors from NUREG/CR-6909 and the air curves from the ASME Code – and that this will produce a more conservative CUFen. See id.

There is no dispute that the Fen factors in the CUFen Reanalyses and the Confirmatory CUFen Analysis were calculated in accordance with the older guidance documents: NUREG/CR-5704 for stainless steel and NUREG/CR-6583 for carbon and low-alloy steel. Entergy and the NRC Staff concede that NUREG/CR-6909 is based on a larger database and more recent and precise data than was used in the earlier NUREGs, at least with respect to stainless steel.[59] But Entergy asserts that it does not need to use NUREG/CR-6909 because the relevant Staff guidance does not require it to do so.[60]

Entergy and the NRC Staff also state that the older NUREGs are generally more conservative, and that if the newer NUREG/CR-6909 methodology were used it would generally

[59] Tr. at 792 (Fair), 842 (Stevens); See also NUREG/CR-6909 at xv.

[60] Fitzpatrick/Stevens Decl. Post Tr. 763, at 26 (Stevens). See also NRC Staff Exh. 13 at 6; Tr. at 794-95 (Fair).

result in less conservative results than the use of existing ASME Code (air) fatigue curves coupled with the methodology of NUREG/CR-5704 and 6583. Tr. at 795-98 (Fair); Entergy Exh. E2-31 at 96-97. Mr. Fair testified that NUREG/CR-6909 had generally less conservative air fatigue curves than the earlier NUREGs for carbon and low-alloy steels and the austenitic stainless steel. Fair Decl. Post Tr. 768, at 4-5. He stated that when Argonne performed the statistical analysis of the test data for metal fatigue in air for NUREG/CR-6909, it determined that the ASME curves for carbon and low-alloy steel were too conservative, and thus NUREG/CR-6909 adopted less conservative air curves. Tr. at 849-50. In addition, the new air curves in NUREG/CR-6909 are based on a less conservative statistical evaluation that is not used in the older NUREGs. Tr. at 790-91, 796-97 (Fair); NUREG/CR-6909 at xvi. Mr. Fair testified that NUREG/CR-6909 states that the ASME air curves (which are used in the older NUREGs) are overly conservative by a factor of 1.7. See Tr. at 850. In addition to such testimony, NUREG/CR-6909 itself states:

> The results suggest that for both carbon and low-alloy steels and austenitic SSs, the current ASME Code requirements of a factor of 20 on cycles to account for the effects of material variability and data scatter, as well as size, surface finish, and loading history, contain at least a factor of 1.7 conservatism. Thus, to reduce this conservatism, [new] fatigue design curves have been developed . . . .

NUREG/CR-6909 at 81. Mr. Fair added that NUREG/CR-6909 shows that the ASME Code design air curves for carbon steel and low-alloy steels in air are more conservative than those in NUREG/CR-6909. See Tr. at 898-99 (Fair); NUREG/CR6909 at A.3 to A.4.

In addition, Mr. Stevens testified that he had recalculated the CUFens for all nine locations covered in the VYNPS LRA using the full methodology (curves and Fens) of NUREG/CR-6909 and found that all nine CUFens were lower than the method proposed by Dr. Hopenfeld (i.e., using a hybrid combination of the ASME air curves and the Fen factors from NUREG/CR 6909). Tr. at 798-802.

ii. Findings

The Board finds that NUREG/CR-6909 contains a larger database of values, more recent data, and is less conservative than the earlier NUREG/CR-5704 and 6583 that were issued by the same NRC contractor – Argonne. The Board also finds that the fact that the NRC Staff guidance indicates that NUREG/CR-5704 and 6583 are sufficient for purposes of license renewal applications is not dispositive of the issue. If the Board found that the use of the more accurate NUREG/CR-6909 was needed in order to provide reasonable assurance that VYNPS metal fatigue will be adequately managed during the PEO, then we would be authorized, and duty bound, to impose such a requirement.

However, the Board finds that Entergy and the NRC Staff have shown that Entergy's use of NUREG/CR-5704 and 6583 in the calculation of the CUFen Reanalyses and the Confirmatory CUFen Analyses is sufficient to provide the reasonable assurance required by 10 C.F.R. § 54.29(a), and that no more is required. The preponderance of the evidence indicates that in this case the use of these older NUREGs is reasonable and conservative and produces TLAA CUFen values that are more conservative than those produced by the calculation method espoused by Dr. Hopenfeld (i.e., a hybrid calculation using ASME air curves and NUREG/CR-6909 Fen equations). While NUREG/CR-6909 is more accurate in certain respects, in this situation its greater accuracy results in less conservatism than the application of NUREG/CR-5704 and 6583, not more.

b. Dissolved Oxygen

i. Evidence[61]

The concentration of DO in the LWR environment is one of the key parameters in calculating the metal fatigue life and the appropriate Fen values for use in the CUFens.[62] As a

[61] Dr. Hopenfeld's rebuttal testimony included a table identifying 13 factors he asserted were of concern with regard to Entergy's calculation of metal fatigue. Hopenfeld Rebuttal Decl. Post Tr. 779, at 4-6. Dr. Hopenfeld testified that DO was one of the three most important concerns from this list. Tr. at 1012-13.

general rule, the concentration of DO in water varies inversely with the temperature of the water. Tr. at 992-93 (Hopenfeld). DO has a different effect on different types of steel – increased DO in the reactor feedwater increases the metal fatigue on carbon and low-alloy steels but decreases it on stainless steels. Tr. at 955 (Stevens), 983 (Hopenfeld).

Dr. Hopenfeld, on behalf of NEC, stated that Entergy's CUFen calculations failed to account for the fluctuations in DO concentrations during the PEO. NEC Exh. NEC-JH_03 at 16-17. He testified that Entergy's use of an average DO value – based on 13 years of daily sampling plus one standard deviation, Tr. at 973-74 (Fitzpatrick) – is a steady state assumption that does not account for the temperature changes that occur during transients. Tr. at 969-70, 974-76.

Dr. Hopenfeld also asserted that Entergy did not explain how the water chemistry data from the feedwater line or the electrochemical potential (ECP) measurements relate to the DO concentration at the component surface during transients. NEC Exh. NEC-JH_03 at 16-17. He testified that the ECP is a more scientifically accurate thermodynamic parameter than DO. Tr. at 962-65.

Dr. Hopenfeld pointed to the statement in NUREG/CR-6909, Tr. at 977, that "A value of 0.4 ppm for carbon and low-alloy steels and 0.05 ppm for austenitic stainless steels can be used for the DO content to perform a conservative evaluation." NUREG/CR-6909 at A.5. He was concerned that Entergy did not use these values. He also cited to page 4-18 of a 2005 EPRI guidance document (referred to as MRP-47) for the proposition that, at a temperature of 550 degrees Fahrenheit the Fen factor for DO should be about 80.[63] Tr. at 986.

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[62] NUREG/CR-6909 at xv ("The key parameters that influence fatigue life in these environments, e.g., temperature, dissolved-oxygen (DO) level in water, strain rate, strain (or stress) amplitude, and, for carbon and low-alloy steels, S content of the steel, have been identified.").

[63] NEC Exh. NEC-JH_64, Materials Reliability Program Guidelines for Addressing Fatigue Environmental Effects in a License Renewal Application (MRP-47 Revision 1), Final Report, Electric Power Research Institute (EPRI) (Sept. 2005) [MRP-47]. Entergy Exh. E2-09, Attach. 2 at 1; Fitzpatrick/Stevens Decl. Post Tr. 763, at 32-33 (Stevens); Tr. at 1031 (Fitzpatrick).

Entergy's exhibits and witnesses explained how Entergy accounted for DO concentration in the metal fatigue Fen calculations. Entergy documents state that, in performing the Fen, Entergy used data from 13 years of daily measurements, including excursions, of DO from the feedwater line. Entergy Exh. E2-09, Attach. 2 at 1-2. For the feedwater piping, Entergy's Fen calculations used a DO value of 50 ppb (i.e., 0.05 ppm), representing the mean of the measured data plus one standard deviation. Id.; Tr. at 974 (Fitzpatrick). For all other locations, Entergy's witnesses stated that they used the EPRI guidance document MRP-47 (also known as the EPRI BWRVIA Model) to determine DO values.[64] In addition, Mr. Stevens testified that the VYNPS uses "hydrogen water chemistry," which is a method to bring reactor water chemistry under control and to reduce the DO concentration. Tr. at 954-55 (Stevens).

With regard to EPRI's MRP-47 (NEC Exh. NEC-JH_64), Mr. Stevens pointed out that he was the principal author of that document, Tr. at 987, and that the graph referred to by Dr. Hopenfeld on page 4-18 of MRP-47 covers conditions that do not exist at VYNPS. Tr. at 987-89. With regard to Dr. Hopenfeld's argument that Entergy should have used the DO values of 0.4 ppm for carbon and low-alloy steels and 0.05 ppm for austenitic stainless steels specified in NUREG/CR-6909, Mr. Fitzpatrick pointed out that the NUREG statement was not prescriptive. Tr. at 997-98 (Fitzpatrick). Mr. Fair clarified that NUREG/CR-6909 calls for the use of the DO values of 0.4 ppm and 0.05 ppm only as default values, when the applicant does not have data as to the actual DO values. Tr. at 998 (Fair). Dr. Hopenfeld agreed. Tr. at 999 (Hopenfeld). In this case, Entergy used data from 13 years of measured DO values. Entergy Exh. E2-09, Attach. 2 at 1-2.

As to the use of DO versus ECP, Mr. Fair acknowledged that although this issue had not been completely settled in the industry, there is very little data on ECP in nuclear reactors and the data is all based on DO. Tr. at 959-60 (Fair). In this context, Dr. Hopenfeld conceded that

[64] Entergy Exh. E2-09, Attach. 2 at 1; Fitzpatrick/Stevens Decl. Post Tr. 763, at 32-33 (Stevens); Tr. at 1031 (Fitzpatrick).

this “is not a major concern” but it is “important to understand” the difference between ECP and DO when calculating Fen and its uncertainties. Tr. at 960-61. He agreed that the ECP factor can be represented by the DO concentration with regard to metal fatigue. Tr. at 964. He also acknowledged that he knew of no practical way that ECP could be measured in a nuclear power plant. Tr. at 965. But, he said, the use of DO as a substitute for ECP raises uncertainty. Tr. at 966.

As to Dr. Hopenfeld’s assertion that Entergy’s DO values fail to account for fluctuations that occur during transients, Entergy presented various rebuttal evidence. First, Mr. Fitzpatrick testified that plant data indicate that DO concentration does not vary significantly during transients. Tr. at 974, 991. In addition, the transients where increased DO was observed (startup and shutdown) are very small contributors to metal fatigue. Tr. at 990 (Fitzpatrick), 1006 (Stevens); Chang Decl. at 12. Mr. Fitzpatrick rejected Dr. Hopenfeld’s assertion that “plain physics” would indicate that DO concentrations in the feedwater must increase dramatically when the water temperature drops, Tr. at 992 (Hopenfeld), explaining that since the feedwater is pressurized, the drop in temperature does not cause a concomitant increase in DO. Tr. at 1034-35 (Fitzpatrick). Mr. Fitzpatrick also noted that if a transient is very rapid, there is a concurrent increase in strain rate that may cancel the effect of the increased DO. Tr. at 1003, 1035. Finally, with regard to fluctuations, Mr. Stevens, the author of MRP-47, pointed out that it recommends that bulk DO levels should be time-averaged before they are used as inputs to the CUFen, and that is the approach that Entergy followed. Tr. at 1004-05 (Stevens).

ii. Findings

The Board finds that Entergy has shown, by a preponderance of the evidence, that its CUFen calculations reasonably account for the effect of dissolved oxygen on metal fatigue at the VYNPS. The use of actual DO data from the feedwater system, as well as the use of industry guidance DO values in other systems, was reasonable and appropriate. The hypothetical use of ECP values instead of DO, while perhaps academically interesting, is not

viable (given the lack of ECP data), nor necessary (given the fact that DO is a reasonable surrogate for ECP and even NEC's witness acknowledged that it is not a major issue). Further, NEC's concerns regarding the fluctuation of DO values during transients are misguided in this situation, where Entergy used actual DO data and otherwise demonstrated that its approach to this phenomenon is sound.

c. Base Metal Cracking

i. Evidence[65]

In the 1970s the feedwater nozzles in a number of boiling water reactor (BWR) nuclear power plants developed cracks due to metal fatigue because of differences in the thermal properties of the cladding and base metal. NEC Exh. NEC-JH_03 at 15. While the cladding was removed in some of these plants, Id.; Tr. at 1040 (Hopenfeld), at the VYNPS the cladding was retained. Tr. at 1040-41 (Fitzpatrick). NEC's witness, Dr. Hopenfeld, stated that Entergy has not provided any proof that the base metal on the feedwater nozzle is not cracked, and therefore Entergy must assume that it is cracked. NEC Exh. NEC-JH_03 at 16. He testified that cracks in the cladding could provide sites for accelerated corrosion and thus accelerated failure under cyclic loads. Tr. at 1054. Dr. Hopenfeld acknowledged, however, that there was no evidence that there actually are any cracks in the VYNPS feedwater nozzles, but asserted that it is a possibility that needs to be considered. Tr. at 1064-65.

Entergy's witnesses testified to Entergy's program concerning potential cracking of the base metal on feedwater nozzles. When the concern first arose many years ago, the feedwater nozzles at VYNPS were inspected, eight cracks were detected and they were ground down. Tr. at 1051 (Fitzpatrick). Penetrant testing of the cladding was periodically conducted. Tr. at 1051 (Fitzpatrick). Subsequently ultrasonic testing (UT) has been instituted and regularly conducted. Tr. at 1051 (Fitzpatrick). The UT inspection technique is the industry standard for detecting

[65] Dr. Hopenfeld testified that base metal cracking was one of the three most important concerns from his list of 13 factors. Tr. at 1012-13.

such cracks, and will detect cracks as small as 3/16 of an inch deep. Tr. at 1051-52 (Fitzpatrick). No such cracks have been detected on the VYNPS feedwater nozzles for the past 20 years. Tr. at 1051-52 (Fitzpatrick). Currently, Entergy does a 100% UT on all four feedwater nozzles every four refueling cycles. Tr. at 1052 (Fitzpatrick). The most recent UT inspection was conducted during the 2007 refueling outage and showed no evidence of cracks in the base metal of the nozzle. Entergy Exh. E2-33, Excerpts from 2007 GE VY Feedwater Nozzle Inspection Report.

Mr. Stevens stated that Entergy's UT inspection program postulates that a crack might develop in the cladding and is designed to detect such an event before it becomes a problem. Tr. at 1062-63. He indicated that the inspection program follows the [ASME Code] Section XI program. Tr. at 1062-63. He added that if any indication of a crack were detected, it would be repaired in accordance with [ASME Code] Section III. Tr. at 1062-63.

ii. Findings

The Board finds that Entergy has shown that it has appropriately considered the possibility of cracking in the cladding inside the feedwater nozzles. Regular and state-of-the-art UT inspections have revealed no such cracks in the last 20 years. Entergy is obligated to continue those inspections during the PEO in accord with its existing in-service inspection program and is obliged to take corrective action if a crack is identified.

d. Surface Finish

i. Evidence[66]

Dr. Hopenfeld testified on behalf of NEC that Entergy's Fen calculations failed to account adequately for the surface roughness of the components in the VYNPS reactor. NEC Exh. NEC-JH_03 at 11. He pointed to Table 12 at page 76 of NUREG/CR-6909 which states that the ASME Code Section III calls for an adjustment factor of four to the ASME fatigue curve (for

[66] Dr. Hopenfeld testified that surface finish was one of the three most important concerns from his list of 13 factors. Tr. at 1012-14.

smooth metal) to account for surface roughness. Tr. at 1070-71. He testified that this shows that roughness in the surface finish of reactor components is a "pretty heavy" and "very important" factor. Tr. at 1071. Dr. Hopenfeld opined that since many of the VYNPS components are low-alloy or carbon steel and have been exposed to the LWR environment for a long time, their metal surfaces are likely corroded and they might have pits and ridges. Tr. at 1073-74.

Entergy and the NRC Staff brought forth several facts in rebuttal. First, Mr. Stevens testified that Entergy indeed complied with the ASME Code and adjusted the air fatigue curve by a factor of four to account for surface roughness. Tr. at 1080. Mr. Fair noted that Table 12 is an example where NUREG/CR-6909 is less conservative than the ASME Code method. Tr. at 1079. This is in part because the ASME Code adjusted its air curve by a factor of four, whereas the NUREG/CR-6909 adjustments were between two and three and one-half. See NUREG/CR-6909 at 76.

ii. Findings

The Board finds that Entergy has adequately accounted for the effects of surface finish in calculating metal fatigue in the structures and components of concern in the VYNPS. Entergy used the more conservative factor of four in adjusting the ASME Code air design curves. NEC has failed to provide evidence that indicates that Entergy did not properly address the issue of surface roughness.

e. Number of Transients

i. Evidence

Dr. Hopenfeld challenged Entergy's "apparent assumption that the number of transients the plant would experience varies linearly with time" because, he asserted, the "failure frequency of pressure vessels (and mechanical and electrical components) is statistically very high later in life due to aging of the plant." NEC Exh. NEC-JH_03 at 16. Dr. Hopenfeld said that Entergy provided no justification for its linear projection, and pointed out (as an illustration

of the invalidity of such a projection) that a linear extrapolation of the two unanticipated transients that VYNPS experienced in August 2007 would predict 912 such transients during the PEO. Id. He opined that the number of transients used by Entergy in its CUFen calculations should be increased by a factor of at least 1.2 to account for the 20% uprate that was recently granted to VYNPS. Id.

Entergy's witnesses testified that they did not do a simple linear extrapolation. Fitzpatrick/Stevens Decl. Post Tr. 763, at 31 (Fitzpatrick). Instead, we were told that the number of transients used in the CUFen analyses represents a combination of the original VYNPS design basis transients, additional, more detailed, design conditions from a later type of boiling water reactor (a "BWR 4"), and the number of transients actually experienced by VYNPS in its first 35 years of operation. Id. at 31-32 (Fitzpatrick). Mr. Fitzpatrick stated that although the original design specification for VYNPS predicted that it would experience 200 startup/shutdown transients over the 40-year life span of the plant, in actuality, the VYNPS experienced approximately 93 such transients in its first 35 years of operation. Id.; Tr. at 860. A straight line projection of 93 startup/shutdown transients over 35 years would predict approximately 160 such transients over the entire 60-year life span (initial 40 years plus PEO of 20 years). Fitzpatrick/Stevens Decl. Post Tr. 763, at 31-32 (Fitzpatrick); Tr. at 860. To be conservative, the LRA assumes 300 startup/shutdown transients over 60 years. Fitzpatrick/Stevens Decl. Post Tr. 763, at 31-32 (Fitzpatrick). Mr. Fitzpatrick stated that the ratio of 300 (projection used in the LRA) to 160 (straight line projection) is 1.875, which exceeds the 1.2 safety factor suggested by Dr. Hopenfeld.[67]

At the Board's request, Tr. at 1161-62, Entergy provided a list of all transients (not just startup/shutdown transients) that have occurred at the VYNPS since it began operation that might impact metal fatigue. Entergy Exh. E2-39; Tr. at 1460-61. This list, which is organized by

[67] Fitzpatrick/Stevens Decl. Post Tr. 763, at 31-32 (Fitzpatrick); Fitzpatrick/Stevens Rebuttal Decl. Post Tr. 763, at 7-9; Tr. at 859-61.

transient type, compares the actual number of transients to-date to the number of transients assumed in Entergy's CUFen analyses to the end of the PEO.[68] The total number of transients experienced to-date (663) is dramatically lower than the number that Entergy used in its CUFen projections (13,806). See Entergy Exh. E2-39.

Testimony was also heard on the topic of the "bathtub curve." Tr. at 862 (Hopenfeld). The bathtub curve is a well known engineering concept, whereby equipment can experience a relatively high failure rate in its initial operational phase; then it enters a long period of stable operations with a low failure rate, and then, toward the end of its operational life, the equipment experiences a higher failure rate. Tr. at 867-68 (Hopenfeld). Dr. Hopenfeld was concerned that the current low numbers of transients at VYNPS reflect the stable period of the bathtub curve and that the facility could experience higher numbers of transients as it ages. See Tr. at 862, 866-69. Mr. Stevens stated that there is no field evidence to support a bathtub curve effect at VYNPS. Tr. at 870-71. He stated that the frequency of startup-shutdown cycles/transients has dropped from once every 12 months at the beginning, to 18 to 24 months now. Tr. at 871. Mr. Stevens testified that extensive experience with the entire fleet of U.S. nuclear reactors shows that, due to learning curve effects, current transients and trips are much less frequent than in the early days, making an even linear extrapolation from the design basis very conservative. Tr. at 871-72. In addition, Entergy's witnesses pointed out that Entergy will be monitoring the number of transients that actually occur against the number assumed in the predictive CUFen analyses, and if the number of actual transients begins to approach the predicted numbers, corrective action will be taken. Tr. at 872 (Stevens), 873-74 (Fitzpatrick).

Entergy's witnesses also testified that their calculations assumed that all transients were at the more severe level of a "design basis transient," as opposed to the lesser severity of the various transients actually experienced at VYNPS. Fitzpatrick/Stevens Rebuttal Decl. Post Tr.

[68] Entergy Exh. E2-39; See also Entergy Exh E2-11, SIA Calculation Package, VY-16Q-302R0, at 18, Table 5; Tr. at 1166-68 (Stevens).

763, at 7-8 (Fitzpatrick). Mr. Stevens testified that when his company, SIA, performed the CUFens for Entergy, they used the transient definitions specified by the plant's designer, which are very conservative because they assume that the changes in temperature and flow occur abruptly. Tr. at 852-53. In addition, Mr. Stevens stated that Entergy/SIA's CUFen calculations accounted for the recent 20% power uprate at VYNPS assuming that all of the transients actually experienced at VYNPS, even those that took place in the decades before the uprate was implemented, occurred at the uprated level (i.e., assumed that they were more severe than they actually were). Tr. at 856, 869-70 (Stevens). The evidence indicated that the actual transients experienced by VYNPS have been much less than those assumed in the design basis, Tr. at 852-53 (Stevens), and the plant has never experienced a thermal transient more severe than design basis. Tr. at 1170 (Fitzpatrick).

ii. Findings

The Board finds that Entergy has been conservative with regard to the number of transients used in its CUFen analyses for metal fatigue. Entergy has not simply done a linear projection as to the number of transients to be expected in the PEO. In addition, we find that Entergy's CUFens are based on increased severity levels that adequately account for the recent 20% power uprate at the VYNPS. The projected number of transients is based on design basis events, actual experience at VYNPS, and industry experience. Even if a bathtub curve appears later in the operational life of the facility, this will be detected and addressed by Entergy's continued tracking of transients. Thus, with regard to the number of transients, the Board finds that Entergy's TLAA calculations are adequate and provide the degree of assurance required by 10 C.F.R. § 54.29(a).

f. Lack of Error Analysis

i. Evidence

Dr. Hopenfeld argued that Entergy should have validated its CUFen analyses by performing an error analysis to show the admissible range for each variable. NEC Exh. NEC-

JH_03 at 18. He asserted that "data scatter in fatigue studies often exceeds an order of magnitude" and therefore when Entergy reports a "CUFen of 0.74 for the RHR Class 1 piping" without providing an error band, this "imparts little confidence that fatigue failure will not occur." Id. Dr. Hopenfeld also asserted that one cannot assume that an estimate is conservative, unless one can quantify the level of conservatism. Tr. at 864.

The NRC Staff and Entergy witnesses posited that an error analysis is not needed. Dr. Chang stated:

> Error analysis is not necessary because conservatism is built into design fatigue curves for carbon steel/stainless steel in the light water environment. As stated in NUREG/CR-6583 and NUREG/CR-5704, these design fatigue curves have been adjusted for uncertainties that are associated with material and loading conditions. Fen values were maximized as practicable consistent with plant conditions. In addition the [Fatigue Monitoring Program] and the Water Chemistry Program will track the transients and chemistry conditions in the analyses to ensure their validity as it relates to transient cycles and Fen values.

Chang Decl. at 10 (corrected page). Mr. Stevens testified to the same effect, saying that it is unnecessary to perform an error analysis "given that bounding input parameters (such as temperature, pressure, and heat transfer coefficients) were selected so as to maximize stresses." Fitzpatrick/Stevens Decl. Post Tr. 763, at 34. He stated that the alternative, using nominal or mean input values in the calculations and then putting an error band on these results, would only produce lower stress predictions and therefore lower CUFen results. Id. Upon questioning, Mr. Stevens acknowledged that not all of the values used in the equations were necessarily bounding (e.g., some of the air curves have a one to five percent chance of not being bounding) but stated that the curves and values have been demonstrated to be very conservative in many studies. Tr. at 911-12 (Stevens). He stated, "If I can demonstrate that my number is very, very conservative and I have an error of two orders of magnitude in the lower direction, then I think just my answer being bounding and conservative" is sufficient. Tr. at 913 (Stevens).

ii. Findings

The Board finds that the lack of an error analysis for each of the variables in the CUFen analyses does not render them inadequate.

g. Heat Transfer Equations

i. Evidence

Heat transfer equations are formulas for predicting the amount of heat that will be transferred between two materials, such as the transfer of heat between flowing water and the metal pipe that contains it. The amount of heat transfer that occurs is a significant factor in calculating thermal stress and metal fatigue and is dependent on factors such as the velocity of the flow. See Tr. at 1104-05 (Hopenfeld), 1105-07 (Stevens).

NEC's expert, Dr. Hopenfeld, asserted that Entergy's CUFen Reanalyses and Confirmatory CUFen Analysis are flawed because Entergy selected inappropriate heat transfer equations. NEC Exh. NEC-JH_03 at 12-15; Tr. at 1096 (Hopenfeld). First, Dr. Hopenfeld stated that Entergy used a heat transfer equation that is applicable to fully developed turbulent flow that would only occur in a long straight pipe. NEC Exh. NEC-JH_03 at 12-13. If flow is not fully developed, there may be localized variations in its velocity, resulting in different amounts of heat transfer, and thus different amounts of metal fatigue. Hopenfeld Rebuttal Decl. Post Tr. 779, at 13. Instead, according to Dr. Hopenfeld, Entergy's heat transfer equation assumes fully developed flow and thus a constant and uniform heat transfer. NEC Exh. NEC-JH_03 at 12-13. Dr. Hopenfeld testified that it is unlikely that the flow in the VYNPS feedwater nozzle is fully developed because the upstream pipe has a straight section only 48 inches in length and a diameter of 9.7 inches, and this, according to an excerpt from a textbook,[69] Dr. Hopenfeld says, is not sufficient for fully developed flow. Id.; Hopenfeld Rebuttal Decl. Post Tr. 779, at 13; Tr. at 1120-21 (Hopenfeld).

[69] NEC Exh. NEC-JH_29, E.R.G. ECKHERT, HEAT AND MASS TRANSFER at 212, Fig. 8-9 (2d Ed. 1959).

Mr. Stevens asserted that the 48 inches of upstream pipe is more than sufficient for fully developed flow to occur. Fitzpatrick/Stevens Decl. Post Tr. 763, at 29. He rejected Dr. Hopenfeld's interpretation of Figure 8-9 from the Eckert textbook on two grounds. First, Mr. Stevens pointed out that Figure 8-9 applies to situations where a "sharp tube entrance" is upstream of the point of concern, whereas in VYNPS, there is only a pipe elbow upstream of the feedwater nozzle. Tr. at 1124. Second, he noted that Figure 8-9 clearly shows that the higher the velocity of the flow, the shorter the distance needed in order for flow to become fully developed. Tr. at 1125. Mr. Stevens testified that the flow velocity in the section of pipe immediately upstream of the feedwater nozzle at VYNPS is high – well off the Figure 8-9 chart – and thus it is appropriate and conservative to use heat transfer equations based on fully developed flow. Tr. at 1125-26.

Dr. Hopenfeld also stated that the CUFens erroneously assume a uniform heat transfer circumferentially around the various components, such as nozzles. Tr. at 1109-11. He stated that since such components are not axisymmetric, the flow velocity may be higher at one part of the nozzle than at another part, making the amount of heat transfer, stress, and metal fatigue different at these different locations. See Tr. at 1108-11. Mr. Stevens agreed that higher velocities would produce higher heat transfer, but asserted that since Entergy had used the higher heat transfer value for the entire nozzle, the variation was not a problem and their calculations were conservative.[70] Tr. at 1111-13.

NEC alleged that Entergy misused the heat transfer equations in several other ways. Dr. Hopenfeld stated that the equations must be corrected to account for the ratio of viscosities at the "bulk and wall temperatures during each transient." NEC Exh. NEC-JH_03 at 13. He stated that "one must assume that the connecting pipe is at some angle with respect to the nozzle and therefore the axixsymetrical [sic] assumption is not valid." Id. at 14. He is

[70] The heat transfer equation issues related to the use of simplified Green's function methodology are discussed in Section III.C.3.h.

concerned that the heat transfer equations might not adequately represent the situation where flow changes from forced convection to natural convection. Id. Dr. Hopenfeld also stated that one of the heat transfer equations is only applicable to laminar flow and defines an average heat transfer coefficient, rather than using the more appropriate local heat transfer coefficient. Id. at 15. Mr. Stevens, in his testimony, responded at some length to each of these assertions, demonstrating how his calculations addressed each of NEC's concerns. See Fitzpatrick/Stevens Decl. Post Tr. 763, at 29-31.

ii. Findings

The Board finds that, with the exception of the Green's function issues discussed at Section III.C.3.h below, Entergy has shown that it has appropriately applied heat transfer equations in its calculation of the effects of the VYNPS environment on the metal fatigue CUFens. Dr. Hopenfeld's concern that it was inappropriate to assume that the flow at the feedwater nozzles is fully developed has not been substantiated and instead has been fairly rebutted by the evidence presented by Mr. Stevens and Mr. Fitzpatrick. Nor is there fair indication that Dr. Hopenfeld's other concerns are warranted.

h. Simplified Green's Function Methodology

i. Evidence[71]

When Entergy performed its CUFen Reanalyses, NEC challenged them as inadequate (Contention 2A), in part because Entergy used the simplified Green's function methodology.[72]

[71] The issue of the Green's function also arose, albeit in a substantially different procedural posture, in the Commission's recent decision in Oyster Creek. In the instant case, the Green's function issue arose long before the evidentiary hearing, via an admitted contention, and has been litigated, and decided, on the merits of the facts, evidence, and law. In contrast, in Oyster Creek, the Green's function issue arose long after the close of the evidentiary record, and the issuance of the Board's decision. In Oyster Creek the Commission affirmed the Board's ruling that the petitioners failed to meet the burden of showing that the adjudicatory proceeding should be reopened under 10 C.F.R. § 2.326(a). Amergen Energy Co., LLC (License Renewal for Oyster Creek Nuclear Generating Station), CLI-08-28, 68 NRC __, __ (slip op. at 15-17) (Nov. 6, 2008). Oyster Creek does not reach the merits of the issue presented in this case.

Subsequently, the NRC Staff raised questions about the same issue. The FSER provides some of the details concerning the interchange between the Staff and Entergy relating to the Green's function. See FSER at 4-38 to 4-43. As a consequence, Entergy performed the Confirmatory CUFen Analysis on the feedwater (FW) nozzle, eliminating the use of the simplified Green's function methodology with regard to this one component. NEC then filed Contention 2B asserting that the Confirmatory CUFen Analysis did not resolve the problem.

Much of the evidence concerning the simplified use of the Green's function is not in dispute. Entergy's CUFen Reanalyses used a simplified approach, by incorporating a single stress term, in applying the Green's function to calculate the CUF for the VYNPS core spray, reactor recirculation, and feedwater nozzles.[73] See Fitzpatrick/Stevens Decl. Post Tr. 763, at 19 (Stevens).

The NRC Staff concluded that the Green's function was not acceptable:

> The applicant's implementation of the Green's function input to the software assumes that shear stresses are negligible. This implementation is a simplified NB-3200 analysis for regular piping . . . . It is numerically adequate at the safe end when non-axisymmetric loadings are not applicable. This implementation may not be valid for those locations with geometric discontinuity or non-axisymmetric load cases (e.g., thermal stratifications), which may cause significant shear stresses. Moreover, it is difficult to determine the threshold for when shear stresses are negligible. Therefore, the applicant's implementation for calculating the stress intensity cannot be validated. The staff concluded that the way the software calculates the stress intensity is inconsistent with the ASME Code. Therefore, the staff could not conclude the [CUFen Reanalyses] calculation is valid.

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[72] The Green's function methodology is an analytical technique used to solve a family of mathematical equations derived to model and predict certain observed physical behavior. See e.g., P.M. MORSE & H. FESHBACH, METHODS OF THEORETICAL PHYSICS (1953). In Entergy's LRA, it was used to calculate the stress intensity from fluid flow in evaluating the cyclic effects of transients on metal fatigue for various reactor components. Consistent with historic industry practice, Entergy simplified this technique to the calculation of a single stress component by assuming shear stresses are negligible. Herein, this approach is called the "simplified Green's function methodology".

[73] The other six of the nine critical locations were not affected by the Green's function problem. Tr. at 928-29 (Stevens).

FSER at 4-38 to 4-39 (emphasis added). Stated another way, "[t]he staff concluded that the way the software calculates the stress intensity through a simplified 1-dimensional ('1-D') stress input to Green's function may not be valid because it simplifies the six stress components discussed in the ASME Code rules into one component of stress." Chang Decl. at 3. The ASME Code calls for stresses to be analyzed using six stress components, thus addressing differences in stress that may occur due to the different loadings or geometry. The CUFen Reanalyses, however, used a simplified Green's function methodology by assuming shear stresses are negligible, and thereby reducing the loading to a single stress component. Tr. at 927-29 (Stevens); NEC Exh. NEC-JH_23 at 2. While this approach may work for a component that has symmetrical loadings around its axis, the NRC Staff did not think it was appropriate for "non-axisymmetric load cases." FSER at 4-38. Accordingly, the Staff asked Entergy for additional information and investigated the matter further. FSER at 4-38 to 4-40.

As a result, Entergy performed the Confirmatory CUFen Analysis on one component – the FW nozzle – eliminating the simplified one-dimensional input to the Green's function and instead using the ASME Code, Section III, Subsection NB-3200 methodology to calculate the stress intensities. Entergy acknowledged that the Confirmatory CUFen Analysis "computed six component stress histories for each transient using the ANSYS finite element computer code, whereas the [CUFen Reanalyses] used a Green's function approach based on a simplified single stress component." Fitzpatrick/Stevens Decl. Post Tr. 763, at 19-20 (Stevens).

Unfortunately, Entergy's initial Confirmatory CUFen Analysis on the FW nozzle did more than just eliminate the use of the simplified Green's function methodology. Entergy also changed the Fen value in the CUFen analysis. Id. at 20. By introducing this second variable (the new Fen value), Entergy obscured the impact of eliminating the over-simplified Green's function. Tr. at 925, 947 (Fair). Thus, in order to produce a true comparison of CUFen results (i.e., CUFens with and without the simplified Green's function methodology) the NRC Staff

required Entergy to re-run the Confirmatory CUFen Analysis without changing the Fen value. Tr. at 1139 (Fair).

This true comparison of CUFens showed that the elimination of the simplified Green's function methodology resulted in a 40% increase in the predicted metal fatigue on the FW nozzle. FSER at 4-43. Specifically, the CUFen Reanalyses resulted in a CUFen of 0.639, whereas the Confirmatory CUFen Analysis produced the 40% higher CUFen of 0.893. FSER at 4-42; Fitzpatrick/Stevens Decl. Post Tr. 763, at 21-22. While the new prediction (0.893) is still below the regulatory requirement (1.000), it is significantly closer to the limit.[74]

The NRC Staff stated: "This indicates that the results of the Green's function application using the specific software could underestimate the CUF, and therefore cannot be the analysis-of-record." FSER at 4-42 to 4-43 (emphasis added). The Staff rejected the CUFen Reanalyses for the FW, CS, and RR nozzles on the ground that these analyses employed a simplified Green's function methodology, "cannot be validated," and are "inconsistent with the ASME Code," Id. at 4-38 to 4-39. The necessary consequence, according to the NRC Staff, is that Entergy must recalculate the CUFens for the FW, CS and RR nozzles, without using the simplified Green's function methodology. Id. at 4-43.

With regard to the FW nozzle, the recalculation has already been done. All parties agree that the Confirmatory CUFen Analysis for the FW nozzle, producing a CUFen value of 0.893, satisfactorily eliminated the simplified Green's function methodology. FSER at 4-43; Tr. at 934, 936 (Hopenfeld); Fitzpatrick/Stevens Decl. Post 763, at 21-22 (Stevens).

The situation is different for the CS and RR nozzles. Here, the only calculations in evidence are the CUFen Reanalyses, which include the use of the simplified Green's function methodology. Entergy took the position that the FW nozzle is bounding, and argued that since

[74] The elimination of the simplified Green's function methodology caused a 40% increase in the CUF. The CUF value was 0.064 in the CUFen Reanalyses and 0.089 in the Confirmatory CUFen Analysis. Fitzpatrick/Stevens Decl. Post Tr. 763, at 21-22. The Fen value (10.05) was constant, therefore the 40% increase in the CUF resulted in a 40% increase in the CUFen.

the Confirmatory CUFen for the FW nozzle is below unity, there is no need to redo the TLAA calculations for the CS and RR nozzles. Fitzpatrick/Stevens Decl. Post 763, at 23 (Fitzpatrick). The Staff disagreed, stating that the CUFen Reanalyses cannot serve as the analyses-of-record for the CS and RR outlet nozzles, and that these calculations need to be redone without using the simplified Green's function methodology:

> The staff reviewed [the Confirmatory CUFen Analysis] and found that for this analysis of the FW nozzle, the stress intensities and the CUFs were calculated in accordance with the ASME Code requirements and the CUF met the Code limit. However, it also showed that the previous analysis was not bounding for the feedwater nozzle using all the same inputs, including Fen values. Therefore, the staff requested that Entergy define this analysis as the "analysis-of-record" for the FW nozzle. . . . [T]he FW nozzle is Vermont Yankee's most FAC-susceptible nozzle. Nevertheless, because the CUF value from the analysis-of-record does not bound the CUF value from [the CUFen Reanalyses], the staff questioned whether the CUF values for CS and RR outlet nozzles . . . which also used the simplified 1-D stress input, are bounding. Thus, the staff imposed a license condition requiring Vermont Yankee to perform ASME Code NB-3200analysis for CS and RR outlet nozzles without using simplified stress inputs.

Chang Decl. at 5. As Mr. Fair testified, "Although the feedwater nozzle analysis is acceptable [the Staff] couldn't make a judgment that the other two nozzles had the same level of conservatism in them that would come out and give a lower result." Tr. at 946. Thus, the NRC Staff proposed the following license condition:

> The fourth license condition requires that the licensee perform and submit to the NRC for review and approval, a ASME Code analysis for the reactor recirculation outlet nozzle and the core spray nozzle at least two years prior to the period of extended operation. These analyses should be documented in the FSAR as the analysis-of-record for these two nozzles.

FSER at 1-12. Thus proposed license condition 4, which is a reversal of the Staff's August 20, 2007 position,[75] would allow Entergy to perform the correct CUFen analyses on the CS and RR outlet nozzles after the renewed license is issued.

[75] NEC Exh. NEC-JH-62 at enclosure 2, NRC Summary of Telephone Conference Call Held August 20, 2007, Between the U.S. Nuclear Regulatory Commission and Entergy Nuclear Operations, Inc., Concerning the Vermont Yankee Nuclear Power Station License Renewal Application (Oct. 25, 2007).

We now turn briefly to evidence concerning how the fourth license condition would be implemented, i.e., the mechanics of how the Staff and Entergy contemplate that the confirmatory CUFen analyses must be performed on the CS and RR nozzles. Mr. Stevens testified that performing the confirmatory CUFen analyses on the CS and RR outlet nozzles would take approximately nine person-weeks of time, per nozzle. Tr. at 920. It is not a straight-forward mechanical calculation. "There's quite a bit involved [including] building a finite element model . . . running 20 [different types of] transients through that finite element model [and] the quality assurance process." Tr. at 919 (Stevens). Technical and scientific judgments are involved in performing the CUFen analysis. Tr. at 919-20 (Stevens).

Mr. Fair testified that, even though the Staff has proposed a license condition requiring that Entergy perform confirmatory CUFen analyses on the CS and RR outlet nozzles, "we didn't specify how they are going to do it." Tr. at 1140. Given the absence of any such instructions, the Board turned to Entergy Commitment 27 as a possible guide as to how the confirmatory CUFen analyses must be done on the CS and RR nozzles. Commitment 27 reads, in full, as follows:

> At least 2 years prior to entering the period of extended operation, for the locations identified in NUREG/CR-6260 for BWRs of the VY vintage, the VY will refine our current fatigue analyses to include the effects of reactor water environment and verify that the cumulative usage factors (CUFs) are less than 1. This includes applying the appropriate Fen factors to valid CUFs determined in accordance with one of the following:
>
> 1. For locations, including NUREG/CR-6260 locations, with existing fatigue analyses valid for the period of extended operation, use the existing CUF to determine the environmentally adjusted CUF.
> 2. More limiting VY-specific locations with a valid CUF may be added in addition to the NUREG/CR-6260 locations.
> 3. Representative CUF values from other plants, adjusted to or enveloping the VY plant-specific external loads may be used if demonstrated applicable to VY.
> 4. An analysis using an NRC-approved version of the ASME code or NRC-approved alternative (e.g., NRC-approved code case) may be performed to determine a valid CUF.
>
> During the period of extended operation, VY may also use one of the following options for fatigue management if ongoing monitoring indicates a potential for a condition outside the analysis bounds noted above:

> 1. Update and/or refine the affected analyses described above.
> 2. Implement an inspection program that has been reviewed and approved by the NRC (e.g., periodic nondestructive examination of the affected locations at inspection intervals to be determined by a method acceptable to NRC).
> 3. Repair or replace the affected locations before exceeding a CUF of 1.0.

FSER at A-8 to A-10 (emphasis added).

Each of the fourteen underlined words or phrases in Commitment 27 leaves a significant element or issue to the discretion, option, or technical judgment of Entergy and the NRC Staff. For example, as Mr. Fair agreed, Entergy gets to decide (1) whether a Fen is "appropriate" to use, (2) whether a more limiting VY-specific location may be added, (3) whether the CUF values from other plants are "representative" and may be used, and (3) whether to perform an alternative NRC-approved approach. Tr. at 1154-56. He agreed that, subject to NRC objection, Entergy gets to decide these issues. Tr. at 1157. He also acknowledged that, while the Entergy-NRC process would be in public, the public would have no right to participate in, or challenge, these discretionary judgment decisions. Tr. at 1157.

ii. Findings

With regard to the Green's function issue raised by NEC, the Board generally agrees with the NRC Staff, and makes the following findings:

1. The Board finds that because the CUFen Reanalyses for the feedwater, core spray, and reactor recirculation outlet nozzles used a simplified Green's function methodology, they are inconsistent with the ASME Code, cannot be validated, could underestimate the nature and extent of metal fatigue at the VYNPS (i.e., underestimate the CUF and CUFen analyses), cannot be the analysis-of-record, and do not satisfy the requirements of 10 C.F.R. §§ 54.21(c)(1) or 54.29(a).

2. The Board finds that the Confirmatory CUFen Analysis for the feedwater nozzle, which produced the result of 0.893, is satisfactory and complies with the regulatory requirements.

3. The Board finds that Entergy has failed to show that the Confirmatory CUFen Analysis for the feedwater nozzle proves that the metal fatigue on the core spray and reactor recirculation outlet nozzles during the period of extended operation (i.e., the CUFens) will necessarily be below the regulatory requirement of unity, i.e., that it is bounding.

4. The Board finds that Entergy must perform the metal fatigue analyses on the core spray and reactor recirculation nozzles (i.e., the CUFens) in compliance with the ASME Code requirements and without using the simplified Green's function methodology in order to satisfy the ASME Code requirements and 10 C.F.R. §§ 54.21(c)(1) and 54.29(a).

5. The Board finds that performance of the confirmatory CUFens on the core spray and reactor recirculation nozzles as specified in the preceding sentence involves a considerable amount of technical and scientific judgment and is not a minor or ministerial task.

6. The Board finds that the NRC Staff's proposed license condition four, whereby Entergy would be required to perform confirmatory CUFen analyses on the core spray and reactor recirculation outlet nozzles, does not specify how these complex computations and judgments should be made.

7. The Board finds that Entergy's Commitment 27, which might be used to govern or apply to the Entergy's duty to perform the confirmatory CUFens on the core spray and reactor recirculation nozzles, gives Entergy many options and discretionary decisions (subject to later NRC Staff review) in addition to the technical and scientific judgment specified in finding five above.

i. Dr. Hopenfeld's CUFen Recalculations

i. Evidence

As a final factual matter, we turn to the CUFen recalculations that Dr. Hopenfeld performed and submitted for each of the nine locations covered by Entergy's CUFens. NEC Exh. JH-03 at 19-20. In all but one case, Dr. Hopenfeld's CUFens exceed the regulatory standard of unity, usually by a large margin. For example, Dr. Hopenfeld calculated a CUFen of

13.77 for the RR outlet nozzle, 12.75 for the FW nozzle, and 10.37 for the RR inlet nozzle. Id. at 20. Dr. Hopenfeld stated that his recalculations were based on the CUF values that Entergy used in its original application (LRA Table 4.3-3) multiplied by the Fen values of NUREG/CR-6909. Id. at 19.

Mr. Stevens and Dr. Chang did not agree with Dr. Hopenfeld's recalculations. First, Mr. Stevens pointed out that the CUF values in the original LRA were generic values taken from NUREG/CR-6260 for B.31.1 piping that were not VYNPS specific. Fitzpatrick/Stevens Decl. Post Tr. 763, at 36. He asserted that the use of generic values is no longer justified because Entergy's CUFen Reanalyses and Confirmatory CUFen Analyses provide CUFs based on actual VYNPS data and conditions. Id. Dr. Chang agreed. Chang Decl. at 11.

Dr. Chang rejected Dr. Hopenfeld's use of the Fen values from NUREG/CR-6909, stating that he inappropriately used only the worst case Fen values (17 for carbon steel and 12 for stainless steel) from NUREG/CR-6909 without supporting or establishing that such worst-case environmental loading conditions were actually present at VYNPS. Id. at 10. Dr. Hopenfeld offered no reason for selecting the factors of 17 and 12 except that they were provided in the NUREG. Tr. at 1134.

Dr. Chang, Mr. Stevens, and Mr. Fair all pointed out that it was improper to selectively use only the Fen values from NUREG/CR-6909 because those values were designed to be used in the context of NUREG/CR-6909, which also revised the air curves and changed the statistical confidence levels for computing CUFen values.[76]

ii. Findings

The Board finds that Dr. Hopenfeld's CUFen recalculations are unsound. The recalculations use ASME default values for the CUF calculation, despite the fact that actual values and conditions are known and available. The recalculations inappropriately use an

[76] Chang Decl. at 10-11; Fitzpatrick/Stevens Decl. Post Tr. 763, at 27-28, 36; Fair Decl. Post Tr. 768, at 4-5.

isolated portion of the NUREG/CR-6909 approach, without applying the other necessary components of that NUREG. And the recalculations use the worst-case Fen values from NUREG/CR-6909 without valid justification. As was elicited in testimony during the hearing, Dr. Hopenfeld's recalculations predict that the regulatory requirement (i.e., unity) would have been exceeded within 4.63 years after the VYNPS commenced operations, and it is obvious to the Board that this did not occur. Tr. at 1129-30.

C. Legal Analysis and Conclusions

1. Timing of Metal Fatigue Aging Analysis

Having concluded that Entergy's metal fatigue analyses on the core spray and reactor recirculation outlet nozzles do not comply with the ASME Code and do not provide reasonable assurance as required by 10 C.F.R. §§ 54.21(c)(1) and 54.29(a), respectively, the key question is as follows: Is it legally permissible and technically appropriate to issue the license now, and allow Entergy to postpone the necessary metal fatigue analyses until later?

Our answer is – no. As we explain below, awarding Entergy a license now, and allowing it to postpone the performance of the necessary "analysis-of-record" TLAA, is inconsistent with the language, structure, and intent of the Part 54 regulations, is inconsistent with NRC precedent,[77] and would violate the intervenor's right under Section 189(a) of the Atomic Energy Act to have a hearing on an issue material to the licensing decision.[78] To defer determining such a significant safety issue until after the license has already been issued would impermissibly remove it from the opportunity to be reviewed in the hearing process.

As an initial matter, we find that an accurate calculation as to whether components such as the core spray and reactor recirculation outlet nozzles are likely to fail during the PEO is a

[77] Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit 2), CLI-74-23, 7 AEC 947, 950-52 (1974) ("the mechanism of post-hearing resolution must not be employed to obviate the basic findings prerequisite to an operating license.").

[78] Union of Concerned Scientists v. NRC, 735 F.2d 1437 (D.C. Cir. 1984).

critical part of the license renewal proceeding. These components are part of the "reactor coolant pressure boundary" and are subject to the "highest quality standards practical." 10 C.F.R. Part 50, Appendix A, GDC 30. Accordingly, the CUF must be calculated correctly, and in accordance with the ASME Code. This was not done for the CS and RR nozzles. In addition, given the undisputed fact that the LWR environment (e.g., water, high temperature, high pressure, transients, non-smooth metal surfaces) can cause a substantial acceleration of metal fatigue, the Board concludes that the CUF must be adjusted to account for such environmental factors (i.e., the CUF must be adjusted with the Fen) in order to provide reasonable assurance that metal fatigue failure will not occur. An LRA analysis of metal fatigue that ignored the known and substantial effects of the LWR environment (the Fen) would be insufficient, both as a technical matter and as a legal matter under 10 C.F.R. § 54.21(c)(1)(i), (ii) or 54.29(a).

The language, structure, and intent of Part 54 make clear that a license renewal applicant cannot postpone performance of the analysis-of-record (i.e., the predictive TLAA that determines whether an AMP is needed) until after the license is issued. Section 54.21 states that the license renewal application must contain an "evaluation" of TLAAs. 10 C.F.R. § 54.21(c)(1). The rule "explicitly requires that (1) Applicants perform an evaluation of time-limited aging issues . . . and (2) the adequate resolution of TLAA issues as part of the standards for issuance of a renewed license." 60 Fed. Reg. at 22,479. The regulation establishes two basic alternatives. The applicant must demonstrate either that aging will not cause the component to fail during the PEO under 10 C.F.R. § 54.21(c)(1)(i) or (ii), or that the effects of aging will be adequately managed during the PEO under 10 C.F.R. § 54.21(c)(1)(iii). The first option – demonstrating that aging will not cause the component to fail – is done via a predictive "time-limited aging analysis." This becomes the "analysis-of-record" and obviates the need for an AMP. The second option is available if an applicant "cannot or chooses not to" do such a TLAA and requires the applicant to demonstrate that it will adequately manage aging during the PEO, i.e., submit an adequate AMP. 60 Fed. Reg. at 22,480.

In this context, the Board agrees with the NRC Staff's original position:

> It is the NRC position that in order to meet the requirements of 10 C.F.R. § 54.21(c)(1), an applicant for license renewal must demonstrate in the LRA that the evaluation of [TLAAs] has been completed. The NRC does not accept a commitment to complete the evaluation of TLAA prior to the period of extended operations.[79]

In contrast, the NRC Staff now argues that Entergy's proposal is entirely legal and permissible. The Staff justifies this reversal of position on the sole ground that Entergy changed the label on its "commitment to complete the evaluation of TLAA," now calling it an AMP under 10 C.F.R. § 54.21(c)(iii) rather than a delayed TLAA under 10 C.F.R. § 54.21(c)(1)(ii). The Staff stated:

> [O]n September 17, 2007 (NRC Staff Exh. 22), Entergy changed its course again. In Amendment 31, Entergy stated that an assessment of the impact of the reactor water environment on critical components will be part of its fatigue monitoring program ("FMP") . . . and thus the effects of aging will be adequately managed in accordance with 10 C.F.R. § 54.21(c)(1)(iii). . . . Therefore, the Staff did not change its interpretation of § 54.21(c)(1). Instead, Entergy temporarily indicated that it would rely on § 54.21(c)(1)(ii), before ultimately relying upon § 54.21(c)(1)(iii).[80]

This is an example of form over substance. Entergy re-labeled its TLAA as an AMP and the Staff now deems it compliant.

The Board rejects the proposition that compliance can be achieved by re-packaging and postponing a TLAA analysis-of-record and calling it an AMP. First, such an interpretation would collapse 10 C.F.R. § 54.21(c)(1)(ii) into subsection (iii), subsuming the former into the latter. If an applicant could demonstrate compliance now by promising to demonstrate compliance later (i.e., satisfy the TLAA analysis-of-record requirement by agreeing to perform it later), there would be no reason or incentive for an applicant to perform the TLAA now. Indeed, there would

[79] NEC Exh. NEC-JH-62 at enclosure 2, NRC Summary of Telephone Conference Call Held August 20, 2007, Between the U.S. Nuclear Regulatory Commission and Entergy Nuclear Operations, Inc., Concerning the Vermont Yankee Nuclear Power Station License Renewal Application (Oct. 25, 2007).

[80] NRC Staff's Brief In Response to Board Order (July 9, 2008) at 3-4 (emphasis added) [Staff Response].

be many reasons (e.g., costs, avoidance of the hearing process) to postpone the TLAA demonstration until later. The new interpretation promoted by Entergy and endorsed by the Staff would render 10 C.F.R. § 54.21(c)(1)(ii) superfluous, thus violating a cardinal rule of statutory and regulatory interpretation.[81]

Second, such an interpretation would violate the structure and intent of 10 C.F.R. § 54.21(c)(1), which requires that the demonstration be in the application, i.e., prior to the issuance of the license renewal. As discussed earlier, the applicant must either demonstrate that aging will not be a problem (by submitting a TLAA) or demonstrate that aging will be properly managed (by submitting an AMP). One or the other must be demonstrated before the license can be granted. Entergy is asking for an entirely different thing: license first and demonstration later. This approach avoids the whole point of the license renewal process, which is to demonstrate that aging will not be a problem or that it will be properly managed. Such an approach improperly postpones the key license renewal decision until after the license is issued, and thus does not comply with 10 C.F.R. § 54.21(c)(1)(ii) or (iii).

As a third matter, the NRC Staff's new position – that Entergy's commitment to perform the TLAAs later is an AMP – is inconsistent with the entire FSER. The FSER discusses Entergy's metal fatigue CUFs solely as TLAAs.[82] Likewise, the FSER discusses the metal fatigue Fens as part of the TLAAs.[83] The Staff never discussed the metal fatigue CUFens in the AMP section of the FSER.[84] Presumably, if the Staff really believed that Entergy's proposal to perform the CUFens later was an AMP, it would have discussed the matter in the AMP section of the FSER.

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[81] See Kungys v. United States, 485 U.S. 759, 778 (1988) (It is a "cardinal rule of statutory interpretation that no provision should be construed to be entirely redundant.").

[82] See FSER at 4-22 to 4-43 ("Time-Limited Aging Analyses").

[83] See id. at 4-32 to 4-43 ("Effects of Reactor Water Environment on Fatigue Life").

[84] See id. at 3-1 to 3-507 ("Aging Management Review Results").

Fourth, since 10 C.F.R. § 54.29(a) specifies that a license renewal may not be issued absent a finding that "there is reasonable assurance that the activities authorized . . . will continue to be conducted" safely, the Board concludes that an AMP that consists primarily of a promise to perform a TLAA later (and, if the TLAA comes out greater than unity, to adopt a full AMP later) does not satisfy this regulatory requirement. Postponing the key demonstration does not meet the reasonable assurance test. This result is not changed by the fact that 10 C.F.R. § 54.29(a) speaks in terms of actions that "have been or will be taken." The future tense phrase "will be taken" is simply a recognition that the AMPs described in the LRA are necessarily implemented during the PEO, i.e., in the future, not an authorization to perform TLAA analyses-of-record in the future.

In this respect, the Board sees a clear distinction between predictive TLAAs that are performed as the "analysis-of-record," and tracking TLAAs. There is nothing in the regulations to prevent a licensee from recalculating TLAAs after the license renewal is granted in order to track how the operational CUFs compare to those predicted as TLAAs. Indeed, it is probably good practice. However, if a TLAA is to serve as the "analysis-of-record" that (1) predicts that aging will NOT be a problem during the PEO and (2) establishes that an AMP is not required, then the TLAA must be done prior to the grant of the license. The predictive analysis-of-record that serves to excuse the licensee from the need to have any further AMP cannot be postponed until after the license is issued.[85] Thus, with regard to the predictive TLAAs, we agree with the Board in the recent Indian Point proceeding when it ruled:

> Entergy's proposal to perform the modified calculations [CUFens] in the future, albeit in accordance with specified guidance, is unacceptable because these

[85] The Board also notes that an applicant is not required to do a predictive TLAA "analysis-of-record" at all. "If an applicant cannot or chooses not to justify or extend an existing [TLAA]," 60 Fed. Reg. at 22,480 (emphasis added), then it can still satisfy the regulation by demonstrating that the effects of aging will be adequately managed for the PEO. 10 C.F.R. § 54.21(c)(1)(iii). But, if an applicant seeks to use a predictive TLAA as the "analysis-of-record" that serves to avoid the need for an AMP, then the analysis must be "of record" before the license is issued, not afterward.

> calculations are not a component of an AMP, but are the fundamental fatigue analyses for time-limited aging that 10 C.F.R. § 54.21(c) requires to be included in the LRA.[86]

As a fifth consideration, it is our conclusion that the Staff's interpretation – which would postpone consideration of important and material nuclear safety issues until after the license is issued – improperly abridges NEC's hearing rights under Section 189(a) of the Atomic Energy Act.[87] Under the AEA, petitioners have a right to an adjudicatory hearing on any material public safety-related issue.[88] The determination as to whether Entergy has adequately demonstrated that the CS and RR outlet nozzles on the reactor coolant pressure boundary will not fail during the period of extended operation is a significant safety determination that is material to whether the license renewal should be granted under 10 C.F.R. §§ 54.21(c)(1) and 54.29(a). The interpretation espoused by Entergy would abridge NEC's hearing rights because it would defer the metal fatigue TLAA demonstration until after the close of the ASLB proceeding and thus eliminate the ability of the intervenor to challenge the applicant's metal fatigue methodology and implementation.[89]

This litigation has amply demonstrated that the proper performance of accurate metal fatigue analyses on the CS and RR outlet nozzles is not a minor or ministerial action that may be left for the applicant and NRC Staff for post-hearing resolution. Entergy's own witness testified that it would take nine person weeks, per nozzle, to perform the confirmatory CUFen analyses, stating that it involves technical and scientific judgment, the construction of a complex finite element model, running 20 different kinds of transients through the model, and performing

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[86] Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), LBP-08-13, 67 NRC __, __ (slip op. at 113) (July 31, 2008).

[87] 42 U.S.C. § 2239(a)(1)(A) ("the Commission shall grant a hearing upon the request of any person whose interests may be affected.").

[88] See Union of Concerned Scientists, 735 F.2d at 1446.

[89] 10 C.F.R. § 2.206 is not a substitute for participation in an adjudication. Washington Pub. Power Supply Sys. (WPPSS Nuclear Project 3), ALAB-747, 18 NRC 1167, 1175 (1983).

quality assurance. Tr. at 919-21 (Stevens). It is not a mechanical repetition of the Confirmatory CUFen Analysis on the FW nozzle. Even if it were, the fourth license condition proposed by the NRC Staff is utterly silent as to how the confirmatory CUFens on the CS and RR outlet nozzles are to be performed. And even if Entergy Commitment 27 governs the method of performance of these confirmatory CUFens, it (1) does not eliminate the above-referenced technical and scientific judgment-calls inherent in a CUFen calculation, and (2) allows Entergy to make numerous other post-hearing decisions and discretionary judgments in the calculation of the TLAAs. While "certain minor matters may be left to the staff for post-hearing resolution,"[90] this is plainly not such a situation. The proper performance of the confirmatory CUFens on the CS and RR outlet nozzles, and the validity of the methodologies used, raises complex issues material to the licensing decision that must be subject to the salutary effect of public participation and the opportunity for a hearing.

The demonstration required by 10 C.F.R. § 54.21(c)(1)(i)-(iii) and the reasonable assurance criterion of 10 C.F.R. § 54.29(a) are conditions precedent to the issuance of a license renewal. The performance of satisfactory confirmatory CUFens on the CS and RR outlet nozzles cannot be consigned to some post-hearing interaction between the NRC Staff and Entergy where there is no opportunity for NEC or the public to challenge the sufficiency of the methods and judgments that went into the calculation and/or to request a hearing.[91]

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[90] Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), ALAB-788, 20 NRC 1102, 1159 (1989).

[91] Longstanding NRC precedent confirms that key safety issues must be resolved in the hearing, not post-hearing by the Staff and applicant. See Louisiana Power and Light Co. (Waterford Steam Electric Station, Unit 3), ALAB-732, 17 NRC 1076, 1103 (1983); accord, Cleveland Elec. Illuminating Co. (Perry Nuclear Power Plant, Units 1 and 2), ALAB-298, 2 NRC 730, 736-37 (1975); Washington Pub. Power Supply Sys. (Hanford No. 2 Nuclear Power Plant), ALAB-113, 6 AEC 251, 252 (1973); Commonwealth Edison Co. (Byron Nuclear Power Station, Units 1 and 2), LBP-84-2, 19 NRC 36, 210 (1984), rev'd on other grounds, ALAB-793, 20 NRC 1591, 1627 (1984); Philadelphia Elec. Co. (Limerick Generating Station, Units 1 and 2), ALAB-836, 23 NRC 479, 494 (1986); Pub. Serv. Co. of Indiana, Inc. (Marble Hill Nuclear Generating Station, Units 1 and 2), ALAB-461, 7 NRC 313, 318 (1978).

> [T]he mechanism of post-hearing resolution must not be employed to obviate the basic findings prerequisite to an operating license - including a reasonable assurance that the facility can be operated without endangering the health and safety of the public. In short, the 'post-hearing' approach should be employed sparingly and only in clear cases. In doubtful cases, the matter should be resolved in the adversary framework prior to issuance of license, reopening the record if necessary.

Indian Point, CLI-74-23, 7 AEC at 951-52.

As a final matter, we turn to the argument, raised by Entergy and the NRC Staff just prior to the evidentiary hearing, that the metal fatigue CUFens are not TLAAs and therefore the license renewal can be issued without them. Entergy pointed to the definition of "TLAA" as calculations that "are contained . . . in the CLB," under 10 C.F.R. § 54.3, and said that since Fens are not contained in Entergy's pre-LRA CLB, they cannot be required as a pre-requisite to license renewal.[92] On July 15, 2008, the NRC Staff, despite having consistently characterized the CUFen analyses as TLAAs for years,[93] agreed with Entergy's new argument, stating that NEC has a "misunderstanding of the definition of TLAA and a mistaken belief that CUFen analyses are TLAAs." NRC Staff Reply Brief (July 15, 2008) at 4. Astoundingly, the NRC Staff now argues that Fens are not part of the CLB and therefore "[c]ompletion of CUFen analyses after issuance of a renewed license is not contrary to the Commission's regulations because CUFen analyses are not TLAAs as defined in § 54.3." Id.

We reject this argument on several grounds. First, as a matter of regulatory interpretation, it is clear that the CLB and TLAAs change and evolve. The plant's original licensing basis is not a static set of requirements that never changes during its 40 or 60-year operating life. The definition of "CLB" recognizes that it will change over the course of a power

[92] Entergy's Answer to Licensing Board Questions (July 9, 2008) at 2-3 [Entergy Response].

[93] The NRC Staff discussed the CUFens in Section 4 of the FSER – "Time-Limited Aging Analyses." As recently as July 8, 2008, the Staff consistently referred to the CUFens as TLAAs. See NRC Staff's Brief in Response to Board Order (July 8, 2008) at 5 ("Issuance of a renewed license with a condition requiring performance of certain TLAA CUFens prior" to the PEO is permissible.).

plant's existence.[94] Likewise, license renewals cannot be issued unless there is reasonable assurance that licensed activities will be conducted in accordance with "any changes made to the plant's CLB in order to comply with this paragraph." 10 C.F.R. § 54.29(a) (emphasis added). "The CLB represents the evolving set of requirements and commitments for a specific plant that are modified as necessary over the life of a plant to ensure continuation of an adequate level of safety." 60 Fed. Reg. at 22,473; Turkey Point, CLI-01-17, 54 NRC at 9 (emphasis added). We reject the suggestion that TLAAs are frozen at some instant prior to the LRA. We conclude that, in the context of a license renewal, the term "time-limited aging analysis" appropriately incorporates both the metal fatigue analysis previously embedded in the applicant's licensing basis (e.g., the CUF), and the environmental adjustment factors (Fen) that current science and NRC policy (GSI-190 Memo) have determined are clearly necessary to accurately assess whether the component is likely to fail due to metal fatigue during the PEO. To purport to adequately assess a component's susceptibility to metal fatigue (and grant a 20-year license renewal) without considering the substantial, known adverse effects of the LWR environment would be folly.

Second, the argument that CUFens are not TLAAs flies in the face of the NRC Staff's entire analysis of the CUFens as TLAAs. The Staff spent thousands of words in the FSER discussing the CUFens as TLAAs. Even the applicant acknowledged Contentions 2A and 2B were TLAA challenges. See Entergy Initial Statement of Position at 4.

Third, even if we posit that the Fens are not part of the TLAAs, in this case it is the CUFs that are defective. Entergy inappropriately used a simplified Green's function methodology in calculating the CUFs for CS and RR outlets. No one contends that the CUF is not a TLAA. Thus, Entergy's argument, that the Fen is not part of the TLAA, is irrelevant, because the defective part – the CUF – is indisputably part of the TLAA.

[94] See 10 C.F.R. § 54.3 (CLB includes "all modifications and additions to such commitments over the life of the license.").

Finally, as stated, the Board concludes that it is essential that the prediction/assessment of the likelihood that the core spray and reactor recirculation outlet nozzles will fail due to metal fatigue during the PEO must include the calculation of both the CUF factor (in air at room temperature), and the environmental adjustment for the Fen factor. The NRC Staff guidance document GSI-190 specifies that the environmental effects of the LWR must be included in the CUF calculations when a license renewal is being considered, and on this point, we agree. We conclude that a promise to perform a CUFen analysis later is not a sufficient demonstration, and it does not provide the reasonable assurance required under 10 C.F.R. § 54.29.

2. Summary, Conclusions, and Consequences

To summarize: the Board finds that Entergy has shown, by a preponderance of the evidence, that its CUFen analyses comply with 10 C.F.R. §§ 54.21(c)(1) and 54.29(a) in all respects, except one. The exception is the CUFen Reanalyses for the core spray nozzle and the reactor recirculation outlet nozzle. The defect in the core spray and reactor recirculation nozzle CUFens is the use of a simplified Green's function methodology that renders them inconsistent with the ASME Code, unable to be validated, and liable to underestimate the nature and extent of metal fatigue at the VYNPS. The current core spray and reactor recirculation nozzles CUFen calculations cannot be the analysis-of-record for these components. In addition, the Board finds that Entergy has failed to show that the Confirmatory CUFen Analysis for the feedwater nozzle necessarily bounds the metal fatigue analyses for the core spray and reactor recirculation nozzles during the period of extended operation.

The Board also concludes that, as a legal and technical matter, the license renewal cannot be authorized or issued until Entergy either (1) properly recalculates the CS and RR outlet nozzle CUFens such that they demonstrate that these important components will not fail during the PEO (i.e., that the calculations produce a value less than unity), or (2) submits an AMP that demonstrates that aging of these components will be adequately managed during the PEO. Such recalculations (or an adequate AMP) cannot be consigned to some post-hearing

activity, because they are a condition precedent to the license, involve complex scientific and technical judgments and discretion, and are not merely ministerial. Thus, the NRC Staff's proposed license condition 4 and Entergy's Commitment 27 do not suffice. Such recalculations (or an adequate AMP) are a pre-requisite to issuance of the license renewal.

The consequence is that the license renewal may be issued only if the above pre-conditions are met, i.e., our authorization of any license renewal is contingent on these pre-conditions. Assuming Entergy still wishes to pursue this license renewal, it must (1) recalculate the CUFen analyses for the CS and RR outlet nozzles, in accordance with the ASME Code, NUREG 6583 and 5704, and all other regulatory guidance, (2) resubmit these results to the NRC Staff and serve them on the other parties herein, and (3) either demonstrate that the TLAAs are less than unity or submit an adequate AMP for these components. At that point we presume (but do not and cannot order) that the NRC Staff will evaluate Entergy's submissions. Presumably NEC will do the same.

If the CUFen analyses are (1) done in accordance with the above stated guidance and the basic approach used in the Confirmatory CUFen Analysis for the FW nozzle, (2) contain no significantly different scientific or technical judgments, and (3) demonstrate values less than unity, then this adjudicatory proceeding terminates. If not, NEC may file a new or amended contention challenging the adequacy of the CUFen calculation,[95] or, if Entergy chooses to proceed under the AMP route, NEC may revitalize dormant Contention 2 (as to the adequacy of Entergy's AMP). In light of these possible eventualities, our ruling today can only be a partial initial decision, and this ASLB proceeding will remain open until 45 days after Entergy performs the confirmatory CUFen analyses on the CS and RR nozzles, the NRC Staff approves them, and Entergy serves NEC and Vermont with full written results of such analyses. If no motion

[95] NEC may not, however, use any such challenge as an opportunity to rehash or renew any technical challenges that have already been raised and resolved in this proceeding (e.g., dissolved oxygen, outdated equations, etc.), but rather must specifically state how the new analyses are not consistent with the legal requirement and the calculations performed for the feedwater nozzle.

involving any such new, amended, or revitalized contention is filed by the 45th day, the adjudicatory proceeding on these matters shall be terminated.

IV. CONTENTION 3

A. Specific Background

1. Specific Procedural History

NEC Contention 3 is a safety contention that deals with the aging management program for the Vermont Yankee steam dryer. The contention reads as follows:

> 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 131, 187 (2006).

Contention 3 was submitted with NEC's original petition. NEC Petition at 17. In essence, it asserts that Entergy's AMP for the steam dryer fails to "demonstrate that . . . the effects of aging on the intended function will be adequately managed for the period of extended operation" as required by 10 C.F.R. § 54.21(a)(3). Id. In its petition NEC argued that Entergy's AMP for the steam dryer was inadequate to detect crack propagation and growth because it was "not based on actual measurement of crack initiation and growth, but instead rel[ied] on theoretical calculations of computer models – the Computational Fluid Dynamic [CFD] Model and the Acoustic Circuit [ACM] Model." Id. NEC asserted that the predictions generated by these models must be confirmed by "hands-on" assessment. Id. This is particularly important, NEC urged, because the VYNPS had recently been granted a 20% extended power uprate (EPU) that had increased the stresses on the steam dryer and increased the possibility that parts would break off and cause safety hazards. Id. at 18.

Entergy opposed admission of this contention, arguing that NEC had ignored information in the docket that showed that the VYNPS steam dryer AMP included visual inspections and monitoring of certain plant parameters in addition to the computer code predictions contested by NEC. Entergy Answer to NEC at 26-30. Entergy asserted that NEC was obliged to consider

that information, which was originally submitted as part of the EPU proceeding before a different Board, and argued that Contention 3 was merely an effort to revive a contention that had been dismissed in the EPU proceeding. Id. at 26.

The NRC Staff admitted that Contention 3 was within the scope of a license renewal proceeding to the extent that it challenged the adequacy of the two computer models but argued that it was nevertheless inadmissible because the opinions offered by NEC's expert witness were "conclusory." Staff Answer to NEC at 12.

The Board found Contention 3 to be admissible. LBP-06-20, 64 NRC at 190. The existence of the EPU steam dryer inspection and monitoring program was not dispositive, we ruled, because the EPU program only continued until 2012, whereas the license renewal period would continue until 2032. Id. at 189. When Contention 3 was admitted, the Board did not know what steam dryer monitoring and inspection program would be implemented during the period of extended operations, or whether it would demonstrate that the aging of the steam dryer would be adequately managed until 2032.[96] Id.

On April 19, 2007, Entergy filed a motion for summary disposition of Contention 3.[97] In support of its motion Entergy stated that the CFD and ACM models, which it had used in connection with the EPU application to develop inputs to estimate the stresses on the steam dryer for comparison with the American Society of Mechanical Engineers (ASME) fatigue

[96] Subsequently, Entergy filed a motion for leave to file a motion for reconsideration of Contention 3. Entergy's Motion for Reconsideration of the Board's Decision to Admit [NEC]'s Contention 3 (Oct. 2, 2006). The Board denied this motion. Memorandum and Order (Denying Entergy Motion for Leave to File Motion for Reconsideration of NEC Contention 3) (Dec. 13, 2006) at 4 (unpublished).

[97] Entergy's Motion for Summary Disposition of [NEC]'s Contention 3 (Steam Dryer) (Apr. 19, 2007) [Entergy MSD of Contention 3].

endurance limits, would not be used as part of the AMP for the steam dryer during the license renewal period.[98]

NEC opposed Entergy's motion, claiming that the facts concerning Entergy's use of the ACM and CFD models and the validity of these models were still in genuine dispute, and that an AMP consisting solely of visual inspection and parameter monitoring would not be sufficient to ensure the dryer's structural integrity.[99]

The Board granted Entergy's motion in part and denied it in part. The Board granted the motion for summary disposition "(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 inferences that the steam dryer is not continuously monitored as part of the aging management program for the license renewal period."[100] Our decision was based on Entergy's unequivocal representations that the CFD and ACM models would not be used or relied upon in the AMP and that the steam dryer would be continuously monitored during the period of extended operations. Id. at 10-11. The Board denied the motion as to the remainder of Contention 3 in regards to the adequacy of Entergy's AMP for the steam dryer. Id. at 12.

2. Specific Legal Standards and Issues

In contrast to Contentions 2A and 2B, Contention 3 is an AMP contention. Specifically, it alleges that Entergy's application does not include an adequate steam dryer AMP.

As discussed above, 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii), and 54.29(a) provide the applicable legal standards for the approval of Vermont Yankee's AMP for the steam dryer. The

[98] Id. at 6, 11-12. See also Declaration of John R. Hoffman in Support of Entergy's Motion for Summary Disposition of NEC Contention 3 (Apr. 18, 2007) at 8. ("The aging management plan for the license renewal period, consisting of the monitoring and inspection activities described above, does not depend on, or use, the CFD and ACM computer codes or the [finite element method] conducted using those codes.").

[99] New England Coalition, Inc.'s (NEC) Opposition to Entergy's Motion for Summary Disposition of NEC's Contention 3 (Steam Dryer) (May 10, 2007) at 3-5 [NEC Answer to Entergy MSD].

[100] Memorandum and Order (Ruling on Motion for Summary Disposition of NEC Contention 3) (Sept. 11, 2007) at 3 (unpublished).

scope of Part 54 is determined by 10 C.F.R. § 54.4, which identifies the plant systems, structures, and components that are within the scope of the regulation. These include safety-related systems, structures, and components, as well as "[a]ll nonsafety-related systems, structures, and components whose failure could prevent" safety-related systems, structures, and components from performing their safety-related functions. 10 C.F.R. § 54.4(a)(2). The steam dryer is not a safety-related structure. Hoffman/Lukens Decl. at 5. However, as noted in the Joint Stipulations and NEC exhibits, its failure could cause loose parts, which may interfere with the operation of safety-related components.[101] Thus, the steam dryer is within the scope of Section 54.

Pursuant to 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii), Entergy must demonstrate that its AMP for the steam dryer is adequate to manage the effects of aging so that the functionality of the safety-related systems, structures and components will be maintained during the period of extended operation (PEO). In addition, pursuant to 10 C.F.R. § 54.29(a), the Board must find there is "reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the CLB." Accordingly, Entergy is required to establish an AMP that provides "reasonable assurance" that the Vermont Yankee steam dryer will not fail so as to prevent the functioning of the safety-related systems, structures and components during the PEO. Entergy must demonstrate that its steam dryer AMP is adequate, and that it satisfies the "reasonable assurance" standard by a preponderance of the evidence. Zion Station, ALAB-616, 12 NRC at 421.

3. Evidentiary Record

a. Identification of Witnesses

During the evidentiary hearing on Contention 3, a total of six witnesses provided fact and/or opinion testimony on behalf of Entergy, the Staff, and NEC. All of the witnesses were

[101] Joint Stipulation at unnumbered page 1; NEC Exh. NEC-JH_54 at 3; NEC Exh. NEC-JH_56 at 3.

found to be qualified to present their testimony on the matters they addressed. As previously stated, written direct testimony was submitted for all of the parties' witnesses, and written rebuttal testimony was submitted by Dr. Joram Hopenfeld for NEC. All of the witnesses also provided oral testimony in response to questioning by the Licensing Board.

Entergy presented two witnesses in support of its LRA. They were: (1) Mr. John R. Hoffman, P.E., a mechanical and nuclear engineer with over 37 years of experience in the nuclear power industry; and (2) Mr. Larry D. Lukens, a nuclear engineer with a background in applying industry codes to operations at VYNPS. On May 12, 2008, Entergy submitted its joint direct declaration for Mr. Hoffman and Mr. Lukens, which was later submitted as an exhibit. Hoffman/Lukens Decl. The Hoffman/Lukens Decl. was later corrected, admitted into evidence, and incorporated into the transcript as if read.[102] Tr. at 1187.

Mr. Hoffman received a Bachelor of Engineering degree in Mechanical Engineering from the Cooper Union for the Advancement of Science and Art and a Master of Science degree in Nuclear Engineering from the University of Lowell. Entergy Exh. E3-02, Resume of John R. Hoffman, P.E.. Mr. Lukens received a Bachelor of Science degree in Nuclear Engineering from the University of Wisconsin. He is also a Licensed Reactor Operator. Entergy Exh. E3-03, Resume of Larry D. Lukens.

The NRC Staff presented three witnesses to provide testimony on Contention 3. They were: (1) Mr. Kaihwa R. Hsu, a mechanical engineer with over 26 years of experience in the nuclear power industry; (2) Mr. Jonathan G. Rowley, a Project Manager with over 14 years of experience in materials science and engineering and over 3 years of experience in nuclear reactor regulation; and (3) Mr. Thomas G. Scarbrough, a mechanical engineer with over 30 years of technical experience in nuclear engineering. On May 13, 2008, the NRC Staff submitted an affidavit from Messrs. Hsu, Rowley and Scarbrough, which was later submitted as

[102] The testimony in this declaration is cited herein as Hoffman/Lukens Decl Post Tr. 1187, at xx (Hoffman or Lukens).

an exhibit. Hsu/Rowley/Scarbrough Decl. The Hsu/Rowley/Scarbrough Decl. was corrected, admitted into evidence, and incorporated into the transcript as if read.[103] Tr. at 1190.

Mr. Hsu received a Bachelor of Science degree in Civil Engineering from Chung Yuan Christian College and a Master of Science degree in Civil Engineering specializing in Structural Mechanics from the University of South Carolina.[104] Mr. Rowley received a Bachelor of Science degree in Materials Science and Engineering from Virginia Polytechnic Institute and State University and a Master of Science degree in Materials Science and Engineering from the University of Texas at Arlington.[105] Mr. Scarbrough received a Bachelor of Arts degree in Physics from Rollins College, a Bachelor of Nuclear Engineering degree from Georgia Institute of Technology, and a Master of Science degree in Mechanical Engineering from the University of Maryland.[106]

NEC presented a single witness, Dr. Joram Hopenfeld, in support of NEC Contention 3. The prefiled declarations of Dr. Hopenfeld that were submitted by NEC in association with Contentions 2A and 2B and that are discussed and referenced in Section III.A.3.a above, also include his direct and rebuttal written testimony on Contention 3. Likewise, Dr. Hopenfeld's credentials were discussed in that section.

b. Identification of Exhibits

Entergy submitted 16 exhibits relevant to Contention 3, numbered E3-01 to E3-16. These included, inter alia, the Joint Declaration of Entergy's experts and their resumes; documents regarding modifications to the steam dryer monitoring and inspection programs, and various procedures for monitoring of plant parameters and moisture carryover; GE SIL-644 and

[103] The testimony in this declaration is cited herein as the Hsu/Rowley/Scarbrough Decl. Post Tr. 1190, at xx (Hsu, Rowley, or Scarbrough).

[104] NRC Staff Exh. 4, Statement of Professional Qualifications of Kaihwa R. Hsu.

[105] NRC Staff Exh. 4, Statement of Professional Qualifications of Jonathan G. Rowley.

[106] NRC Staff Exh. 4, Statement of Professional Qualifications of Thomas G. Scarbrough.

other documents concerning the steam dryer inspection program; the qualification requirements for personnel; and summaries of inspections of the steam dryer and the results of the inspections. These exhibits were admitted into the record. Tr. at 1187-88.

The NRC Staff submitted four exhibits relevant to Contention 3, numbered NRC Staff Exhibits 4, 14, 15 and 19. These include its witnesses' affidavit concerning NEC Contention 3; the VYNPS license amendment from the power uprate; a cover letter on the report on the results of steam dryer monitoring; and relevant sections of NUREG 1800. These exhibits were admitted into the record. Tr. at 1190-91.

NEC submitted eight exhibits in support of Contention 3, numbered NEC Exhibits NEC-JH_54-61. These include Dr. Hopenfeld's direct testimony and report evaluating Entergy's AMP for the steam dryer; certain sections of the license application; amendments to the application; the NRC Staff's FSER; and other documents referenced in the report. In its rebuttal testimony, (NEC Exh. 2), NEC submitted an additional two exhibits, numbered NEC Exhibits NEC-JH_68-69. These include an evaluation of the steam dryer inspection indications performed by Entergy and an article on monitoring nuclear power plant components for degradation. These exhibits were admitted into the record. Tr. at 778-80.

c. Relevant Staff Guidance Documents

1. NUREG-1800, Rev. 1 "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (Sept. 2005) (NRC Staff Exh. 19). NUREG-1800 recommends that applicants for license renewal with approved EPUs commit to perform "an operating experience review and its impact on aging management programs for systems, structures, and components before entering the period of extended operation." NUREG-1800 at 3.0-2.

2. NUREG-1801, "Generic Aging Lessons Learned (GALL) Report" (Sept. 2005) (NRC Staff Exh. 7; Entergy Exh. E3-08) (GALL Report). NUREG-1801 calls for a plant-specific aging management program to be developed. NUREG-1801 at IV B1-6.

B. Findings of Fact

1. Joint Stipulations

Entergy, the NRC Staff, and NEC have submitted the following seven joint stipulations with respect to Contention 3:

> (1) In 2002, steam dryer cracking and damage to components and supports for the main steam and feedwater lines were observed at the Quad Cities Unit 2 nuclear power plant. Loose parts were shed by the dryer due to metal fatigue failure of the dryer caused by flow-induced vibration.
>
> (2) The Quad Cities 2 experience raised a concern that a loss of physical integrity of the dryer could result in the release and migration of loose dryer sections or parts to other components and could thus have adverse impact on safety-related equipment.
>
> (3) The existence of cracks on the surface of a steam dryer needs to be identified and evaluated before the cracks progress to the point where they could cause a loss of physical integrity of the dryer, resulting in loose parts.
>
> (4) In Section 3.1.2.2.11 of the License Renewal Application, Entergy addresses aging management of the VY steam dryer as follows:
>
> > Cracking due to flow-induced vibration in the stainless steel steam dryers 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 exception to that document.
>
> (5) GE-SIL-644 recommends that BWR licensees institute a program for the long term monitoring and inspection of their steam dryers. It provides inspection and monitoring guidelines.
>
> (6) The monitoring component of the proposed VY steam dryer management program consists of assessing the status of the steam dryer by the plant's operators and VY's technical staff through the continuous monitoring of certain plant parameters.
>
> (7) With respect to dryer inspections during plant refueling outages, the details of the visual inspection program to be implemented are set forth in the section of GE-SIL-644 devoted to BWR-3 steam dryers, which is Appendix C, pp. 15-16. The dryer inspections are to be performed in accordance with the VY BWRVIP Program Plan, VY-RPT-06-00006 (Exhibits E3-12) and GE-SIL-644, Revision 1.

Joint Stipulation at unnumbered pages 1-2.

2. Factual Findings on Key Contested Matters

The potential for fatigue cracking of steam dryers in boiling water reactors (BWR) such as VYNPS to cause problems became apparent as a result of an incident at the Quad Cities Unit 2 nuclear power plant mentioned in the Stipulations. Joint Stipulation at unnumbered page 1. Although the steam dryer is not a safety-related component, cracking of a dryer could cause a release of loose parts that could have an adverse impact on safety-related equipment by becoming lodged in places that might impede the function of other reactor components that do perform safety-related functions. Id.

The issue before this Board is the allegation by NEC that Entergy's LRA does not include an adequate AMP plan to monitor and manage aging of the steam dryer during the PEO. LBP-06-20, 64 NRC 131, 187 (2006). A more narrow statement of NEC's concern is whether Entergy has proposed a program to manage aging of the VYNPS steam dryer that will provide reasonable assurance that the steam dryer will be maintained in accordance with the CLB during the PEO. NEC Initial Statement at 20. Three specific sub-issues are presented by NEC in its Statement of Initial Position: (1) the sufficiency of Entergy's assessment program for steam dryer monitoring data; (2) the qualifications of the personnel who will evaluate this information; and (3) whether the AMP should include stress analysis for comparison to fatigue limits as a component of the plan. Id.

a. Overview of Entergy's Steam Dryer AMP

The purpose of the SDMP is to detect steam dryer failures and to shut down the reactor promptly so as to minimize the challenge to the safety-related components and therefore to reduce risk to public safety. Tr. at 1404 (Hoffman). Dr. Hopenfeld asserted that a public safety hazard would result if parts of the steam dryer broke loose and were transported by flow or gravity to other areas of the reactor. Hopenfeld Decl. Post Tr. 779, at 8.

Under the LRA, Entergy's proposed AMP for the steam dryer is split into two branches, one that would go into effect immediately (i.e., if and when the LRA is granted) and another that

will spring into effect later, if certain contingencies occur. Specifically, the LRA references these two branches as follows:

> Cracking due to flow-induced vibration in the stainless steel steam dryers 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 exception to that document.

LRA section 3.1.2.2.11; Joint Stipulation at unnumbered page 2.

In the first branch of the steam dryer AMP, Entergy will continue to follow its existing BWR Vessel Internals Program (BWRVIP). Mr. Hoffman testified that this BWRVIP stems initially from the modifications that Entergy made to the steam dryer in anticipation of an extended power uprate (EPU) to VYNPS in order "to improve its capability to withstand the higher flow induced vibration loadings that could result from operation of the plant at EPU levels." Hoffman/Lukens Decl. Post Tr. 1187, at 7. He added that these changes, as described in Supplement 8 to Entergy's EPU Application, were performed to improve the structural strength of the steam dryer. Id. (citing Entergy Exh. E3-04). Mr. Hoffman stated that, as a part of the EPU, Entergy implemented its Steam Dryer Monitoring Plan (SDMP), Exhibit E3-05 herein. Id. at 7-8. The SDMP, according to Mr. Hoffman, was also described in Supplement 33 of the EPU Application. Id. at 7. He stated that the SDMP was approved by the NRC Staff and included as a license condition to the EPU License Amendment. Id. Thus, the first branch of Entergy's proposed steam dryer AMP is Entergy's current SDMP, which is referred to in the LRA section 3.1.2.2.11 and the Joint Stipulations as the "BWRVIP." As stated in that section of the LRA, the BWRVIP/SDMP incorporates the guidance of General Electric's Services Information Letter (SIL) No. 644 (GE-SIL-644). LRA section 3.1.2.2.11.

The SDMP and GE-SIL-644 consist of two main elements – continuous monitoring and visual inspections. First, the SDMP requires Entergy to monitor, on a continuous basis, certain plant operational parameters (such as main steam line flow, reactor vessel water level, and

steam dome pressure) supplemented with periodic measurements of moisture carryover that would be symptomatic of a loss of steam dryer structural integrity.[107] The second component of the SDMP requires Entergy to conduct visual inspections of the steam dryer at specified intervals when VYNPS is undergoing refueling outages (RFOs).[108] Mr. Hoffman testified that the under the existing license, which expires in 2012, Entergy is required to conduct visual inspections of the steam dryer during the RFOs in fall 2005, spring 2007, fall 2008, and spring 2010. Hoffman/Lukens Decl. Post Tr. 1187, at 8. As a part of the LRA, Entergy has committed to "continue inspections in accordance with" the SDMP during the PEO. FSER at A-12 (Commitment 37). See also Hoffman/Lukens Decl. Post Tr. 1187, at 8.

The second branch of Entergy's proposed steam dryer AMP will come into effect only if certain future events occur, and focuses on a nascent EPRI guidance document entitled BWRVIP-139 (which is a revised version of the current BWRVIP and which also incorporates GE-SIL-644). Tr. at 1235-36 (Scarbrough). BWRVIP-139, and an even newer iteration BWRVIP- 139A, are currently undergoing NRC Staff review for possible NRC approval. Tr. at 1194-95 (Rowley), 1235-37 (Scarbrough). Under the LRA, Entergy "will evaluate BWRVIP-139 once it is approved by the staff [and] either include its recommendations in [the steam dryer AMP] or inform the staff of [Entergy's] exception to that document." Joint Stipulation at unnumbered page 2. According to Mr. Scarbrough, BWRVIP-139 provides detailed steam dryer information, that includes:

> (1) [D]iscussion of steam dryer configurations for different plants, (2) summary of steam dryer operating experience, (3) discussion of susceptibility for fatigue cracking and intergranular stress corrosion cracking, (4) discussion of failure modes and effects of cracking in steam dryer components, (5) discussion of relative stresses in different steam dryer components, (6) inspection recommendations for different steam dryer designs, (7) examples of evaluation

[107] Hoffman/Lukens Decl. Post Tr. 1187, at 8; Exh. E3-05 at 3; GE-SIL-644 at 7 and Appendix D (Monitoring Guidelines).

[108] Hoffman/Lukens Decl. Post Tr. 1187, at 8; Exh. E3-05 at 7; GE-SIL-644 at 6-7 and Appendix C (Inspection Guidelines).

approaches for steam dryer cracking, and (8) operational guidance for monitoring moisture carryover.

Hsu/Rowley/Scarbrough Decl. Post. Tr. 1190, at 5-6.

According to the LRA and Mr. Lukens, if the NRC Staff approves BWRVIP-139, Entergy will evaluate the document and either accept its recommendations or inform the NRC Staff of any of its exceptions to the document. LRA section 3.1.2.2.11; Tr. at 1221. However, if the NRC Staff does not approve of BWRVIP-139 prior to the PEO, Entergy has committed to continue inspections in accordance with the SDMP, Revision 3. FSER at 3-56, Appendix A, Commitment 37. BWRVIP-139, according to Mr. Lukens, was issued by EPRI and submitted to the NRC Staff in 2005. Tr. at 1216-17. He asserted that the document is proprietary and to his knowledge, is not available to the public. Tr. at 1216. According to Mr. Scarbrough, the NRC Staff should make a decision on whether to approve the document some time in fall 2008. Tr. at 1217.

In the following sections we will consider NEC's principal arguments and challenges in support of Contention 3.

b. Need to Predict or Measure Stress Loads on Dryer

i. Evidence

Dr. Hopenfeld states that Entergy's steam dryer AMP must include some means of estimating and predicting stress loads on the steam dryer for comparison to ASME fatigue limits. Hopenfeld Decl. Post Tr. 779, at 8. He asserts that mere "visual inspection and monitoring of plant parameters," i.e., only the collection of data, is insufficient and that it must be complemented by some mechanism for using that data to predict or estimate whether and when the steam dryer will fail. Id. at 9. Mr. Hoffman responds to NEC's assertion by declaring that the AMP need not include any predictive mechanism because the parameter monitoring component, supplemented by the periodic visual inspections during refueling outages, is sufficient to diagnose whether significant dryer cracking has occurred before such cracking

results in dryer failure. Hoffman/Lukens Decl. Post Tr. 1187, at 9. In this context, dryer 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 and potentially migrate to other components. Hoffman Decl. Post Tr. 1187, at 6.

Dr. Hopenfeld testified further that he believes that it was a mistake to remove the instrumentation for the determination of the loads on the dryer, referring to strain gauges that, for purposes of the EPU, were placed in the main steam lines to obtain data on pressure fluctuations within the main steam flow. Hopenfeld Steam Dryer Report at 8. The data were used as inputs to calculate pressure loads on the steam dryer and to calculate the resulting stress in steam dryer components. Id. at 4. Later, Dr. Hopenfeld stated that the only way to demonstrate that you will not have a dryer failure is to do predictive calculations, or by instrumenting the dryer. Tr. at 1351. Mr. Lukens addressed the practicality of providing strain gauges on the dryer itself. Tr. at 1380-83. He concluded that the welding of strain gauges to the dryer could cause stresses where none existed before, that it would be difficult to get the electrical wires out of the reactor vessel, and that this instrumentation itself could be a source of loose parts. Tr. at 1380-81.

Mr. Hoffman testified that Entergy performed extensive stress analysis prior to the recent EPU, and that the predicted loads on the dryer were shown to be below the endurance limit. Hoffman Decl. Post Tr. 1187, at 33-34. As a result, he stated that the design analysis was not time-limited and thus does not need to be revisited at the license renewal stage, where only time-limited aging analyses need to be evaluated. Id. at 34. Further, he stated that the loadings on the dryer derived from plant geometries (pipe lengths, diameters, flows, pipe connections, etc.) that have not changed since the uprate was implemented. Id. Therefore, according to Mr. Hoffman, there is no reason for further analytical efforts to provide continued instrumentation to measure loadings. Id. at 34.

ii. Findings

While the adequacy of the stress analyses performed by Entergy prior to the 2006 EPU is not a subject for consideration by this Board, we can infer from the fact that the EPU was granted that these analyses were considered adequate at the time they were performed. Because no further power uprates have been requested for the PEO, we expect reactor geometries and operating conditions to remain unchanged for this period. Since the 2006 EPU analyses yielded predicted loads below the endurance limit, we find that the design analysis is not time-limited and thus does not need to be revisited during the PEO. For these reasons, the stress analyses remain applicable throughout the PEO, and we find it to be unnecessary to repeat them, particularly since the results would not change. Therefore, we reject the assertion by Dr. Hopenfeld that some means must be provided for predicting the stress loads on the steam dryer.

We now turn to Dr. Hopenfeld's allegation that it was a mistake to remove the instrumentation from the main steam lines and his assertion that the dryer itself should be instrumented. We will deal first with the issue of the removal of the instrumentation from the main steam lines. We find that this instrumentation was installed as a temporary measure as part of the EPU to measure pressure fluctuations during the uprate period that might provide a source for acoustical waves to produce high-frequency pressure loadings on the steam dryer components. These loadings, in turn, could lead to high-cycle fatigue and ultimately to failure of the steam dryer. The Board has no testimony indicating that the measurements obtained from these instruments provide any direct indication of stresses on the steam dryer. Instead, we find that these measurements only serve to provide input data for the computer analyses discussed above. We are persuaded by the testimony of Mr. Hoffman that there have been no changes in plant operating conditions that would cause these measurements to differ from the values that were obtained during the EPU. We do not see a need to repeat this analysis. Because the calculations have been completed, there is no longer any use for the data that would be

obtained from the pressure instrumentation. We therefore reject the contention of Dr. Hopenfeld that it was a mistake to remove the instrumentation from the main steam lines and conclude that there is no longer any necessity to continue to monitor acoustical pressure fluctuations in the main steam lines.

We next consider Dr. Hopenfeld's claim that strain gauges should be placed directly on the steam dryer. He asserts that such gauges would be of tremendous use because they would answer the question of where the stresses are compared to the endurance limit. Dr. Hopenfeld has made no suggestion about how such strain gauges might be attached to the dryer and how the signals might be transmitted outside the pressure vessel. Tr. at 1384. However we are persuaded by Mr. Lukens testimony that there is no practicable way of providing this instrumentation and that, even if it were possible to do so, it would likely lead to an increased danger of loose parts in the system. Tr. at 1380-81. While we agree with Dr. Hopenfeld that the data from strain gauges attached directly to the dryer might be of significant value, we find that there is no practical method for carrying out these measurements. We therefore reject Dr. Hopenfeld's claim that this instrumentation must be installed at VYNPS.

c. Parameter Monitoring Component of Steam Dryer AMP

i. Evidence

We next turn to the issue of the adequacy of the parameter monitoring component of Entergy's SDMP. This consists of continuous monitoring of certain reactor parameters, supplemented by periodic measurements of the moisture carryover. The visual inspection component of the SDMP is discussed in the next section.

Dr. Hopenfeld testified that fatigue cracking from high-cycle, flow-induced vibrations cannot be monitored and that monitoring moisture carryover is not reliable as an indicator of potential dryer disintegration. Tr. at 1243. In his Steam Dryer Report, Dr. Hopenfeld quotes GE-SIL-644, Entergy Exh. E3-09, as stating the limitations of parameter monitoring as follows:

"monitoring steam moisture content and other reactor parameters does not consistently predict imminent dryer failure nor will it preclude the generation of loose parts."[109]

Mr. Hoffman, speaking for Entergy, testified that they have a procedure, ON-3178 (Entergy Exh. E3-07), that calls for immediate power reductions and eventual shutdown of the reactor if changes are detected in certain monitored parameters that might indicate steam dryer cracking that could lead to the increased risk of loose dryer parts in the system. Tr. at 1270. According to this procedure, if unexplained changes occur in main steam line flow, reactor vessel water level, or steam dome pressure, the VYNPS operators must take a sample to determine the amount of moisture carryover from the steam dryer. Entergy Exh. E3-07 at 2. The procedure then specifies a sequence of actions, including an engineering evaluation of potential steam dryer damage leading to plant shutdown, depending upon the amount of moisture carryover in the main steam lines. Id. at 2-4. Finally, according to Mr. Hoffman, "it is very unlikely that any damage to the dryer would not also result in a decrease in efficiency of the steam dryer (and thus result in an increase in moisture carry-over and a change in one or more of the monitored parameters.) Hoffman/Lukens Decl. Post Tr. 1187, at 29.

With regard to the ability of the SDMP parameter monitoring program to detect cracking and degradation of the steam dryer before loose parts actually begin falling off of the steam dryer, Mr. Hoffman contended that the monitoring program can detect developing cracks that allow some bypass flow out of the dryer. Tr. at 1296-1300. Mr. Hoffman also made the point that the visual inspection program shows that flaws develop very slowly, so they would not progress to the point of failure in the very short time it would take to shut the plant down. Tr. at 1303. Mr. Hsu also testified that the monitoring program would give early warning before a piece comes off the dryer. Tr. at 1321-22. In responding to subsequent questions, however, Mr. Hoffman declined to give an opinion on how large a crack could be detected by the parameter monitoring program. Tr. at 1336-37.

[109] Hopenfeld Steam Dryer Report at 7-8 (quoting Entergy Exh. E3-09 at 6).

ii. Findings

The evidence from the Quad Cities incidents of 2002 and 2003, in which the reactor twice continued in operation for more than a month with loose parts from a fractured steam dryer with no consequences to the public, undermines Dr. Hopenfeld's assertion of a public safety hazard in these circumstances. Tr. at 1261-62 (Hoffman). That said, continued operation with dryer parts loose in the system carries increased risk and is a situation that should be avoided. The Board has examined the parameter monitoring component of Entergy's SDMP and concludes that it provides adequate assurance that Entergy will halt operations of the VYNPS in a timely manner if the steam dryer begins to generate loose pieces. We believe that the parameters that are monitored on a continuing basis will provide reasonable warning should the dryer actually fail. We find that Entergy is aware of the risks of continued operation with a failed steam dryer and that the parameter monitoring component of the steam dryer AMP is an adequate program for detecting this situation and taking immediate steps to shut the plant down in a timely manner.

Regarding the issue of the ability of this program to detect cracking before the dryer fails, the Board is inclined to agree with Dr. Hopenfeld. We are doubtful that the parameter monitoring program, supplemented by occasional moisture carryover measurements, provides a reliable indicator of the presence of cracks in the steam dryer. We are persuaded, however, as discussed above, that this program can detect severe degradation or actual failure of the dryer, providing Entergy with the information necessary to allow for a timely shutdown of the reactor and thereby providing adequate protection to the public from the risks of continued operation with loose dryer parts in the reactor system.

d. Visual Inspection Component of SDMP

i. Evidence

Dr. Hopenfeld, testifying for NEC, stated that Entergy's proposed program of periodic visual inspection, together with the parameter monitoring and uninformed by knowledge of

stress loads on the dryer, will not provide reasonable assurance that the structural integrity of the steam dryer will be maintained so that generation of loose parts during normal operation, transients, and accident events is prevented. Hopenfeld Decl. Post Tr. 779, at 9. We considered the issue of predicting the stress loads on the dryer in section IV.B.3.b and dealt with the parameter monitoring program in Section IV.B.3.c. In this section, we examine the ability of the visual inspection program to detect fatigue cracking and thereby provide assurance that dryer integrity will be maintained. NEC has not provided any specific criticisms of the VYNPS steam dryer visual inspection program, with the single exception that the inspections are limited to exposed, accessible areas of the dryer. Hopenfeld Steam Dryer Report at 3-4.

Mr. Hoffman testified that under Entergy's existing SDMP, it is performing a program of visual inspections of the steam dryer at each of the first three RFOs following the 2006 EPU. Hoffman/Lukens Decl. Post Tr. 1187, at 7-8. He stated that one of these inspections (spring 2007) has already been performed and that another two inspections are scheduled for fall 2008 and spring 2010, with a partial inspection scheduled for fall 2011. Id. at 8. Mr. Hoffman added that Entergy has committed to continue performing inspections of the steam dryer during the PEO and that these inspections will be consistent with the guidance given in GE-SIL-644. Hoffman/Lukens Decl. Post Tr. 1187, at 8.

Mr. Hoffman stated that these visual inspections of the steam dryer consist of two types of non-destructive examinations of accessible internal and external welds and plates in the steam dryer that are potentially susceptible to crack formation. Hoffman/Lukens Decl. Post Tr. 1187, at 16. Mr. Hoffman asserted that one type of inspection, a VT-1 examination, determines the condition of a part, component or surface, including cracks, wear, corrosion, erosion, or physical damage on the surfaces of the part or component, and is capable of achieving a resolution to discern a 0.044 inch imperfection on the dryer surface. Id. He stated that a second type, a VT-3 examination, is intended to determine the general mechanical and structural condition of components, such as the verification of clearances, settings, physical

displacements, loose or missing parts, debris, corrosion, wear, erosion, or the loss of integrity at bolted or welded connections. Id. at 17. He stated that the VT-3 visual examination is capable of achieving a resolution sufficient to discern a 0.105-inch anomaly. Id. He testified that the technicians who perform these non-destructive examinations and who review these examinations are qualified in accordance with the ASME code. Id.

Mr. Lukens, testifying for Entergy, reports that during the first comprehensive examination of the steam dryer in 2004, done in anticipation of the EPU, twenty "indications" were found by visual inspection, two of which were deemed necessary to repair. Hoffman/Lukens Decl. Post Tr. 1187, at 26; Tr. at 1360. He stated that an "indication" is an imperfection or discontinuity that is detected by nondestructive examination, and not all indications are cracks. Hoffman/Lukens Decl. Post Tr. 1187, at 20. Mr. Lukens explained that "indications" in the steam dryer are evaluated to determine whether they represent potential cracks or are just surface imperfections. Id. at 21. He informed us that these two indications, that were indeed "cracks" and thus needed repair, were ground out and re-welded. Id. at 26; Tr. at 1360. He testified that since the 2004 inspection, Entergy has not identified any steam dryer cracks that are consistent with fatigue,[110] and that this conclusion was supported by the fact that the identified indications have not grown during subsequent operating cycles. Hoffman/Lukens Decl. Post Tr. 1187, at 26. NEC has not challenged the ability of Entergy's inspection program to detect cracks in sections of the steam dryer that are accessible for inspection. Mr. Lukens assures us that the areas of the dryer that are most susceptible to failure are the outer surfaces that are easily accessible for inspection. Tr. at 1369.

Mr. Lukens testified that 66 indications were found during the steam dryer inspection in the fall 2005 RFO. Hoffman/Lukens Decl. Post Tr. 1187, at 23. He added that the steam dryer

[110] Mr. Lukens noted that cracks in BWR steam dryers are one of the following three types: fatigue cracks, intergranular stress corrosion cracks (IGSCC), and stress relief cracks. Hoffman/Lukens Decl. Post Tr. 1187, at 21. He testified that cracks in the steam dryer are typically stress relief cracks and self-arrest when the stress is relieved, whereas IGSCC cracks are short and tight and usually grow in subsequent cycles. Id.

visual inspections conducted during the spring 2007 RFO, following approximately one-year of full power operation at the EPU level, identified 47 of the same 66 indications. Id. at 24. In addition, the 2007 inspection identified 19 new indications, again producing a total of 66 indications for 2007. Id. at 27. He stated that these indications were evaluated by qualified structural engineers experienced in evaluating indications in BWR steam dryers, and each of the indications was accepted to "use as-is," requiring no modification or repair to be made to the steam dryer. Id. He said that no growth was noted in the previously identified indications. Id.

We next turn to the evidence concerning the nature and extent of Entergy's commitment to continue the existing SDMP's visual inspections during the 20-year PEO. On the one hand, the existing SDMP states that visual inspections "shall continue until the completion of one full operating cycle at EPU [and] if an unacceptable structural flaw is detected" then visual inspections shall "extend another full operating cycle" until the inspection program detects "no new flaws/flaw growth." Entergy Exh. E3-05 at 8. Stated otherwise, under the SDMP, Entergy can halt the visual inspection program after a full operating cycle where no new flaws or flaw growth are detected.

On the other hand, the SDMP also states that the visual inspections "will meet the recommendations of SIL-644." Entergy Exh. E3-05 at 7. GE-SIL 644 recommends that the operator (1) "repeat the visual inspection of all susceptible locations . . . during each subsequent refueling outage," (2) "continue the inspections at each refueling outage until at least two full operating cycles," and (3) after two full operating cycles . . . repeat the visual inspection of all susceptible locations . . . at least once every two refueling outages." Exh E3-06 at 7.

Meanwhile as part of the LRA process, Entergy has committed to "continue inspections in accordance with the [SDMP]." FSER at A-12 (Commitment 37). But, as shown above, this commitment is ambiguous because under the SDMP, visual inspections may be discontinued after an operating cycle with no cracks, whereas under GE-SIL-644, visual inspections must be

conducted at every RFO for two operating cycles and thereafter must continue at least once every two RFOs.

The Entergy and Staff witnesses testified that the latter interpretation is correct, i.e., that Entergy's commitment, in its steam dryer AMP, means that it must continue visual inspections during the entire PEO. Tr. at 1210-11 (Lukens); Tr. 1206, 1212 (Rowley).

ii. Findings

While the parameter monitoring program discussed in IV.B.3.c above is limited in its ability to detect cracks in the steam dryer, the visual inspection component of the SDMP and steam dryer AMP has this capability, but only at RFOs when the steam dryer is accessible for inspection. Visual inspections at VYNPS have identified a large number of indications, and several cracks, so we have reasonable confidence in their ability to identify existing cracks prior to actual failure of the dryer. We will deal with the possibility that a crack can initiate and propagate to failure within the 18 or 36-month period between inspections in the next section. The Board concludes that the visual inspection program is capable of alerting Entergy to the initiation or growth of cracks in the steam dryer that might result in the release of debris or pieces that could interfere with the functioning of the VYNPS safety-related structures, systems or components.

With regard to the nature and extent of Entergy's commitment to continue to conduct visual inspections during the PEO, we find that the language of the SDMP, Commitment 37, and GE-SIL-644 is equivocal and unclear. On the one hand, the specific language of the SDMP would allow the discontinuation of visual inspections after one full cycle with a clean bill of health. On the other hand, GE-SIL-644 recommends that visual inspections be continued (albeit less frequently) indefinitely. Entergy and the NRC Staff assure us that the latter interpretation is correct. However, in light of the ambiguity, and the fact that the testimony during the July 21-24, 2008 evidentiary hearing is not likely to be readily remembered during the entire PEO, the Board requires that any renewal license include an express condition that visual

inspections of the steam dryer will continue during the PEO in accordance with the frequency specified in GE-SIL-644 at page 7. We articulate this condition in the legal conclusions below.

e. Potential for High-Cycle Fatigue Failure

i. Evidence

Dr. Hopenfeld asserted that the 2006 EPU increased steam velocity at VYNPS "and thereby increased the potential for creation of fluctuating pressure loading that could damage the steam dryer." Hopenfeld Decl. Post Tr. 779, at 9. Mr. Hoffman testified for Entergy that dryer failures are caused by high-cycle fatigue cracking and that failure will either occur shortly after a change is made to reactor operating conditions or not occur at all, presumably because the stresses are below the endurance limit for the dryer. Hoffman/Lukens Decl. Post Tr. 1187, at 33. Because the VYNPS has operated for more than two years at an uprated power level, Mr. Hoffman maintained that Entergy can eliminate high-cycle fatigue as a cause for cracking. Id. at 28. Dr. Hopenfeld did not agree with this thesis. Tr. at 1316, 1325-26. He believes that failures can occur after eighteen months or more following a change in operating conditions. However, he could not provide the Board with a time period beyond which he believed high-cycle fatigue could be eliminated as a cause for cracking, see e.g., Tr. at 1316, 1326-27, 1385, and was unable to cite any example of a fatigue failure occurring beyond eighteen months. Tr. at 1328. Mr. Scarbrough provided the example of the Quad Cities reactors, which first failed about ninety days following a power uprate, and then failed again about a year later. Tr. at 1328.

Dr. Hopenfeld's assertion that power uprates can cause dryer failures is supported by the evidence of the Quad Cities incidents, which led to the issuance of GE-SIL-644 calling for a program of parameter monitoring, visual inspection, and repair for BWR steam dryers. Entergy Exh. E3-06 at 6. Pursuant to the recommendations of this guidance, Entergy inspected the VYNPS steam dryer and made significant improvements to it in preparation for the 2006 power

uprate. Hoffman/Lukens Dec. Post Tr. 1187, at 7. Entergy has committed to continue to follow the guidance provided in this document. Entergy Exh. E3-05 at 7.

ii. Findings

It is not clear from the testimony given by these witnesses whether Entergy's thesis – that fatigue cracking will either occur rapidly following a power uprate or not at all – is correct. Dr. Hopenfeld took a position contrary to that of Energy, believing that operation for a period of years with no evidence of fatigue cracking of the steam dryer gives no assurance that a crack cannot initiate and propagate to failure within the 18-month interval between inspections, or presumably within the 36 month interval that will be in effect for most of the PEO. However, VYNPS has operated for more than two years at uprated power with no indication of high-cycle fatigue-induced cracking of the steam dryer. This fact is consistent with the analyses of the steam dryer done in preparation for the 2006 EPU, and supports the proposition that the dryer is below the endurance limit for fatigue cracking. The analytical evidence, together with the failure to observe any signs of fatigue cracking in the visual inspections that have occurred following the power uprate, give strong support for Entergy's position. We find that if high-cycle fatigue cracking occurs in the VYNPS steam dryer, the cracking, or its precursor “indications,” will likely be detected by the periodic visual inspections that are made at RFOs occurring every 18 or 36 months during the PEO.

f. Loss of Coolant Accidents

i. Evidence

Dr. Hopenfeld, testifying for NEC, has stated that he believes “that operation of the steam dryer as currently intended by the Applicant is in violation of General Design Criteria (GDC) 1 and Draft GDC-40 and-42 insofar as they require that protection must be provided against the dynamic effects of loss of coolant accidents [LOCA].” Hopenfeld Decl. Post Tr. 779, at 9. This issue is clarified by Dr. Hopenfeld's testimony in which he stated that he believed that a LOCA can cause a failure of the steam dryer. Tr. at 1250. In further testimony, however, he

was unable to articulate either why he believed the dryer would fail during a LOCA or how a failure of the steam dryer during the LOCA would exacerbate the consequences of the accident. Tr. at 1251, 1255-56, 1258-59. Mr. Scarbrough, speaking for the NRC Staff, testified that he knew of no requirement to consider a failure of the steam dryer in association with a loss of coolant accident. Tr. at 1252. He further testified that he does not know of a scenario by which a loose part from the dryer could interfere with the injection of cooling water flow following a LOCA. Tr. at 1253. Entergy's witness, Mr. Hoffman, testified that he believed that the monitoring system at VYNPS would detect dryer degradation before any loose parts are generated, and Entergy would be able to respond before a loose part is generated. Tr. at 1296-97.

ii. Findings

The Board finds that there is insufficient evidence to indicate that the failure of the steam dryer in association with a LOCA is a matter of concern for the PEO. We are persuaded that the likelihood of a LOCA occurring immediately following failure of the steam dryer and before the reactor has been shut down is exceedingly remote. If the events are postulated to occur in the reverse order (i.e., a LOCA causing failure of the steam dryer), we do not find any plausible mechanism for the loose parts that have been shed from the dryer to impede the flow of cooling water into the reactor or to otherwise worsen the progress of such an accident.

g. Qualifications of Personnel

i. Evidence

A further allegation by NEC regarding the existing SDMP is that Entergy has not provided information on the qualifications of the personnel evaluating the monitoring data. NEC Initial Statement at 20. NEC introduced no evidence to support this assertion. Mr. Hoffman testified for Entergy that the personnel involved in determining the significance of SDMP measured parameters are required to be qualified in the application of the operability determination procedure EN-OP-0104 (Entergy Exh. E3-11). Hoffman/Lukens Dec. Post Tr.

1187, at 14. Mr. Hoffman further stated that a prerequisite for procedure qualification is the requirement that the individuals be enrolled in the "Engineering Support Personnel" training program and that their capability to perform independent engineering work be assessed by their supervisor. Id. This is part of Entergy's training program, which includes an annual assessment of individual training needs by the engineer and his or her supervisor. Id.

ii. Findings

NEC has not supported its allegation by responding to the information provided by Entergy regarding their program for personnel qualification. We note that NEC has not contested the actual qualifications of the personnel but instead has simply criticized Entergy for a failure to provide information. The Board has reviewed the evidence submitted by Entergy and finds (1) that it contains an adequate description of the training program and (2) the personnel involved in the parameter monitoring program appear to be properly qualified to administer this component of the SDMP.

h. Second Branch of Steam Dryer AMP – BWRVIP-139

i. Evidence

As discussed in section IV.B.3.a above, Entergy's proposed steam dryer AMP has two branches. The first calls for the continuation of Entergy's existing SDMP into the PEO, whereas the second branch specifies that a new AMP, the BWRVIP-139, will apply if and when certain future contingencies occur. LRA section 3.1.2.2.11; Joint Stipulation at unnumbered page 2. The NRC Staff's decision to approve Entergy's steam dryer AMP is expressly based on both branches and actually emphasizes the contingent BWRVIP-139 branch:

> The staff finds that since the applicant committed to implement BWRVIP-139, if approved by the staff prior to the period of extended operation, this aging effect or mechanism will be adequately managed as recommended by the GALL Report. If the staff does not issue an SER approving the use of BWRVIP-139, steam dryer inspections will continue in accordance with the steam dryer monitoring plan, Revision 3. The steam dryer monitoring plan would also assure that this aging effect or mechanism will be adequately managed.

FSER at 3.175.

The evidence indicates that the second branch of Entergy's steam dryer AMP, the BWRVIP-139 branch, is subject to several contingencies. First, it is contingent on whether NRC approves BWRVIP-139. Tr. at 1194 (Rowley), 1215 (Lukens), 1219 (Scarbrough). It is uncertain whether this approval must come, as specified in the above-quoted section of the LRA and in Commitment 37, "prior to the [PEO]," or not. Second, it is contingent on an iterative process between EPRI and the NRC Staff, whereby industry is already revising BWRVIP-139 and has submitted a new version – BWRVIP-139A – to the Staff. Tr. at 1236 (Hsu), 1219 (Scarbrough). Third, it is contingent on Entergy's decision whether to accept the NRC approved BWRVIP-139 or to take "exceptions" to it. Tr. at 1219 (Scarbrough); FSER at 3-57 and 3-174. Fourth, it is contingent on the NRC Staff approving any Entergy exceptions to BWRVIP-139. Tr. at 1219 (Scarbrough); FSER at 3-174 ("Exceptions, if any, will be subject to review and approval by the staff.").

A second aspect of the BWRVIP-139 is that it is unknown, unavailable, and not in the evidentiary record. BWRVIP-139 is an industry document that is "proprietary" and not available to the public. Tr. at 1216 (Lukens). Nor have the NEC or the State of Vermont seen it. Tr. at 1216 (Lukens). This Board has not seen it and it is not in evidence herein. Tr. at 1217 (Lukens). While the NRC Staff indicates that the process whereby the foregoing four contingencies may occur are public, this will not afford NEC, Vermont, or the public the opportunity to participate in or challenge the currently unfinished and unknown BWRVIP-139.

ii. Findings

In grappling with Contention 3, which challenges the adequacy of Entergy's steam dryer AMP, this Board has attempted to discern what the AMP is. However, the second branch of the steam dryer AMP, the BWRVIP-139 branch, is highly contingent, unknown to the intervenors, and not in evidence. Accordingly, we cannot and do not base our decision upon it. Instead, our

findings on Entergy's steam dryer AMP are based entirely on the first branch of the AMP, the commitment to continue the existing SDMP into the PEO.

In the event that the NRC Staff approves BWRVIP-139, Entergy accepts it, and the other specified contingencies occur, then nothing in this decision precludes NEC, Vermont, or any other possible intervenor from challenging this change in the VYNPS license.

C. Conclusions of Law

Section 54.21(a)(3) and Section 54.21(c)(1)(iii) require Entergy's AMP for the steam dryer to "demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB during the period of extended operation." Meanwhile, Section 54.29(a) does not permit the NRC to issue a renewed license until Entergy provides reasonable assurance that failure of the steam dryer will not interfere with the continued operation of safety-related components and that the activities that the renewed license authorizes will continue to be conducted in accordance with the CLB. It is the burden of the Applicant to show that the AMP for the VYNPS steam dryer meets these criteria, and it must do so by a preponderance of the evidence.

It is our conclusion that, with the proviso noted below, Entergy has shown, by a preponderance of the evidence, that the first branch of its steam dryer AMP (using the current SDMP based on GE-SIL-644) meets these legal requirements. We find that, based on the visual inspection component of the AMP, VYNPS will enter the period of extended operation with a steam dryer that has operated for a period of about six years at uprated power levels with no indication of fatigue cracking. Although it is not possible to state with certainty that a reactor component such as the steam dryer will never suffer a fatigue failure – regardless of how much analysis and how many inspections are performed – we are convinced the likelihood of steam dryer failure for the VYNPS is acceptably small. Furthermore, we are reassured that should dryer failure occur the continuous parameter monitoring component of the AMP provides an acceptable mechanism for detecting this failure and rapidly shutting down the plant. Therefore,

we find that Entergy's steam dryer AMP is adequate to manage aging during the PEO. For the foregoing reasons, we conclude that Entergy has demonstrated by a preponderance of the evidence that the AMP for the steam dryer does provide reasonable assurance that it will continue to perform its intended function through the renewal period.

Our legal conclusion is subject to the mandatory proviso that the renewed license include the following express condition: "Notwithstanding any other provision, Entergy shall continue to perform and implement the continuous parameter monitoring, moisture content monitoring, and visual inspections specified in the AMP, at the intervals specified in GE-SIL-644 Revision 2. These shall continue for the full term of the PEO unless this provision of the license is duly amended."

And, as a final matter, the Board notes again that in evaluating the AMP presented by Entergy, our decision is based entirely on the Steam Dryer Monitoring Plan and the visual inspection program for VYNPS and GE-SIL-644, Revision 2, which is incorporated therein. It is not based on BWRVIP-139.

V. CONTENTION 4

A. Specific Background

1. Specific Procedural History

Contention 4 is a safety contention that deals with flow accelerated corrosion (FAC) in the plant piping. The contention reads as follows:

> Entergy's License Renewal Application does not include an adequate plan to monitor and manage aging of plant piping due to flow accelerated corrosion during the period of extended operation.

LBP-06-20, 64 NRC 131, 192 (2006).

Contention 4 was submitted in NEC's original Petition. NEC Petition at 18. In essence, it asserts that Entergy's AMP for FAC of plant piping fails to "demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB for the period of extended operation" as required by

10 C.F.R. § 54.21(a)(3). NEC took particular exception to Entergy's use of a computer program called "CHECWORKS" to determine the scope and frequency of inspections of pipes and components that are subject to FAC. NEC Petition at 18-19. NEC argued that CHECWORKS could not be used to make accurate predictions because the program needed to be benchmarked to new plant conditions following the extended power uprate (EPU). Id. at 19. The petition stated that "Entergy cannot assure the public that the minimum wall thickness of carbon steel piping and valve components will not be reduced by FAC to below . . . code limits during the [PEO]." Id.

Entergy opposed admission of this contention, arguing that NEC's concerns about CHECWORKS had no basis, and that CHECWORKS was only one of many factors used in planning future inspections. Entergy Answer to NEC at 32. The NRC Staff also opposed the admission of Contention 4, arguing that CHECWORKS was benchmarked with data from many plants and that Entergy's use of CHECWORKS in a comprehensive FAC management program is entirely appropriate. Staff Answer to NEC at 14.

The Board found Contention 4 to be admissible, saying that "[i]t raises a challenge to Entergy's plans for aging management of plant components subject to FAC, and it supports that challenge adequately." LBP-06-20, 64 NRC at 194. At that time the Board noted that, although FAC was also discussed during the NRC Staff's review of Entergy's EPU application, there was no evidence of binding commitments to continue existing programs into the license renewal period. Id. at 195. Even if such a commitment were made, however, the Board noted that NEC's contention raised the issue of "whether a program similar to the current one will be adequate to address the amount of corrosion that may occur during the 20 years of extended operation." Id.

On June 5, 2007, Entergy filed a motion for summary disposition of Contention 4.[111] Entergy argued that summary disposition was appropriate because Contention 4 is "limited to [the] assertion that the FAC program . . . is defective because it relies on the use of CHECWORKS and that code needs to be 'benchmarked' against ten to fifteen years of inspection data," id. at 2-3, whereas, Entergy says, the CHECWORKS code did not need such benchmarking. Therefore, Entergy reasoned, "no genuine issue as to any material fact exists" under 10 C.F.R. § 2.710(d)(2). Id. at 1.

According to Entergy, the CHECWORKS code relied on laboratory data and FAC data from many plants, and therefore it could be used effectively even when plant parameters change significantly following an EPU. Id. at 8-9. Furthermore, Entergy said, inspection data from three scheduled refueling outages under EPU conditions are to be used to improve the CHECWORKS database before the license renewal term begins in 2012. Id. at 9.

NEC disagreed, stating that the declarations of Entergy's expert witnesses in support of the motion were controverted by NEC's two expert witnesses, who disagreed with Entergy "on substantial and technically credible grounds."[112] For example, NEC stated that its experts did not agree with Entergy's experts with respect to the following two issues:

> (1) Whether data collected under the current VYNPS FAC program during three post-EPU refueling outages scheduled prior to the expiration of the current VYNPS license will be sufficient to benchmark CHECWORKS to VYNPS post-EPU conditions; and
>
> (2) Whether the current VYNPS FAC program appropriately implements industry guidance, and will constitute an adequate aging management plan with respect to FAC.

Id.

[111] Entergy's Motion for Summary Disposition of [NEC]'s Contention 4 (Flow Accelerated Corrosion) (June 5, 2007).

[112] [NEC]'s Opposition to Entergy's Motion for Summary Disposition of NEC's Contention 4 (Flow-Accelerated Corrosion) (July 15, 2007) at 3.

The Board denied Entergy's motion, observing that "Entergy has failed to demonstrate the absence of a 'genuine issue of material fact' and that the pleadings instead reveal a 'battle of the experts' of precisely the type that requires denial of the motion for summary disposition and resolution at an evidentiary hearing."[113] The Board ruled that, "[t]he pleadings on their face demonstrate that sharp differences of expert opinion continue to exist in this matter, and we do not see that Entergy has met its burden of demonstrating that no factual disputes exist." Id. at 7.

2. Specific Legal Standards and Issues

Contention 4, similar to Contention 3, is an aging management program (AMP) contention. Specifically, it alleges that Entergy's application does not include an adequate AMP for plant piping subjected to FAC during the PEO. As discussed above, Sections 54.21(a)(3), 54.21(c)(1)(iii), and 54.29(a) provide the applicable legal standards for the approval of Vermont Yankee's AMP for plant piping due to FAC. Pursuant to 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii), Entergy must establish an AMP that is adequate to provide reasonable assurance that the intended function of the piping subject to FAC will be maintained in accordance with the CLB for the PEO. Entergy must demonstrate that its AMP for piping subject to FAC is adequate, and that it satisfies the "reasonable assurance" standard by a preponderance of the evidence. Zion Station, ALAB-616, 12 NRC at 421.

In addition, the Board asked the parties to submit briefs on the following legal issue relevant to Contention 4:

> Does a renewal application that contains a short written description of an aging management program that lacks content or details but instead states that it is 'comparable to' and 'based on' the relevant section of NUREG-1801 or EPRI NSAC-202L, 'demonstrate that the effects of aging will be adequately managed' as required by 10 C.F.R. §§ 54.21(a)(3) and 54.21(c)(1)(iii).

[113] Memorandum and Order (Ruling on Motion for Summary Disposition of NEC Contention 4) (Aug. 10, 2007) at 6-7 (unpublished).

Briefing Order at 5. The parties each submitted responses to our question with both Entergy, Entergy Response at 9-12, and the NRC Staff, Staff Response at 10, arguing, in separate filings, that it is appropriate, and NEC asserting that a more detailed description is required. [NEC] Supplemental Prehearing Brief (July 9, 2008) at 9-10. The Board finds that simply saying that an AMP is "based on", "consistent with" or "comparable to" a NUREG or other document is not adequate. See discussion infra at V.B.2b.ii. However, in this instance we find that Entergy has provided more information than a simple reference to another document.

3. Evidentiary Record

a. Identification of Witnesses

During the evidentiary hearing on Contention 4, a total of seven witnesses provided fact and/or opinion testimony on behalf of Entergy, the NRC Staff, and NEC. All of the witnesses were found to be qualified to present their testimony on the matters they addressed, with the exceptions noted below. As previously stated, written direct testimony was submitted for all of the parties' witnesses and written rebuttal testimony was submitted by Mr. Kaihwa Hsu, Dr. Joram Hopenfeld, Dr. Rudolf Hausler, and Mr. Ulrich Witte. All of the witnesses also provided oral testimony in response to questioning by the Board.

Entergy presented two witnesses in support of its LRA. They were: (1) Dr. Jeffrey S. Horowitz, an independent consultant in the nuclear and mechanical engineering fields, who was the principal creator of the CHECWORKS computer code (and its predecessors CHEC and CHECMATE); and (2) Mr. James C. Fitzpatrick, a civil engineer, who provided support for the Vermont Yankee license renewal project in the areas of FAC and metal fatigue. On May 13, 2008, Entergy submitted its joint direct declaration of Dr. Horowitz and Mr. Fitzpatrick which was later submitted as an exhibit. Horowitz/Fitzpatrick Decl. The Horowitz/Fitzpatrick Decl. was later corrected, admitted into evidence, and incorporated into the transcript as if read.[114]

[114] Tr. at 1427. The testimony contained in this declaration is cited herein as Horowitz/Fitzpatrick Decl. Post Tr. 1427, at xx (Horowitz or Fitzpatrick).

Dr. Horowitz received a Bachelor of Science degree in Mechanical Engineering from the New Jersey Institute of Technology and Master of Science and Doctor of Science degrees in Mechanical Engineering from the Massachusetts Institute of Technology. Entergy Exh. E4-02, Resume of Jeffrey S. Horowitz at 2. Dr. Horowitz has over 36 years of professional experience in the field of nuclear energy, including 22 specializing in FAC and nuclear safety analysis. Horowitz/Fitzpatrick Decl. at 1. During this time, one of his main clients has been the Electric Power Research Institute (EPRI), for which he has created the CHECWORKS program. Id. at 1-2, Entergy Exh. E4-02 at 2. Mr. Fitzpatrick's qualifications are discussed in Section III.A.3.a, supra.

The NRC Staff presented two witnesses in support of its position on Contention 4. They were: (1) Mr. Kaihwa R. Hsu, a senior mechanical engineer formerly of the Division of License Renewal in the NRC's Office of Nuclear Reactor Regulation; and (2) Mr. Jonathan G. Rowley, a materials scientist, who is lead project manager for the safety review of the VYNPS license renewal application. On May 13, 2008, the Staff submitted a joint affidavit from Mr. Hsu and Mr. Rowley which was later submitted as an exhibit. Hsu/Rowley Decl. On June 2, 2008, the NRC Staff submitted the rebuttal testimony of Mr. Hsu which was later submitted as an exhibit. Hsu Rebuttal Decl. The Hsu/Rowley Decl. was later corrected, admitted into evidence, and incorporated into the transcript as if read. The Hsu Rebuttal Decl. was also incorporated into the transcript as if read.[115] The qualifications of the two NRC Staff witnesses are discussed in Section IV.A.3.a, supra.

NEC presented three witnesses in support of Contention 4. They were Dr. Joram Hopenfeld, a mechanical engineer with 45 years of experience, including 18 with the NRC; Dr. Rudolph Hausler, a chemical engineer with over 30 years of experience with an expertise in corrosion prevention; and Mr. Ulrich K. Witte, a specialist in configuration management and

[115] Tr. at 1432. The testimony contained in these declarations is cited herein as Hsu/Rowley Decl. Post Tr. 1432, at xx (Hsu or Rowley) and Hsu Rebuttal Decl. Post Tr. 1432, at xx.

regulatory compliance. On April 28, 2008, NEC submitted written direct testimony by Dr. Hopenfeld in support of its position on Contention 4 which was later submitted as an exhibit. Hopenfeld Decl. On June 2, 2008, NEC submitted the rebuttal testimony of Dr. Hopenfeld which was later submitted as an exhibit. Hopenfeld Rebuttal Decl. This prefiled testimony was admitted into evidence and incorporated in the transcript as if read.[116] On April 28, 2008, NEC submitted prefiled written direct testimony by Dr. Hausler in support of its position on Contention 4 which was later submitted as an exhibit. Hausler Decl. On June 2, 2008, NEC submitted the rebuttal testimony of Dr. Hausler which was later submitted as an exhibit. Hausler Rebuttal Decl. The Hausler Decl. and the Hausler Rebuttal Decl. were admitted into evidence and incorporated in the transcript as if read.[117] On April 28, 2008, NEC submitted prefiled written direct testimony by Mr. Witte in support of its position on Contention 4 which was later submitted as an exhibit. Witte Decl. On June 6, 2008, NEC submitted the rebuttal testimony of Mr. Witte which was later submitted as an exhibit. Witte Rebuttal Decl. The Witte Decl. and the Witte Rebuttal Decl. were admitted into evidence and incorporated in the transcript as if read.[118]

Dr. Hopenfeld's qualifications are discussed in Section III.A.3.a, supra. Dr. Hausler received Bachelor of Science and Master of Science degrees in Chemical Process Technology from the Swiss Federal Institute of Technology in Zurich and a Doctor of Philosophy degree in Chemical Engineering from the same institution. NEC Exh. NEC-RH_02, Resume of Rudoph H. Hausler at 3. Dr. Hausler has over 30 years of chemical research experience focused on corrosion prevention in the oil production industry. Id. at 1. He holds 17 patents and has had 58 articles published in this area. Id. at 4.

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[116] Tr. at 778-79. The testimony contained in these two declarations is cited herein as Hopenfeld Decl. Post Tr. 779, at xx or Hopenfeld Rebuttal Decl. Post Tr. 779, at xx.

[117] Tr. at 1436-37. The testimony contained in these two declarations is cited herein as Hausler Decl. Post Tr. 1437, at xx or Hausler Rebuttal Decl. Post Tr. 1437, at xx.

[118] Tr. at 1439. The testimony contained in these declarations is cited herein as Witte Decl. Post Tr. 1439, at xx and Witte Rebuttal Decl. Post Tr. 1439, at xx.

Mr. Ulrich K. Witte received a Bachelor of Arts degree in Physics from University of California at Berkeley. NEC Exh. NEC-UW_02, Resume of Ulrich K. Witte at 9. He has 26 years of professional experience in engineering, configuration management, licensing and regulatory compliance of commercial nuclear facilities.[119]

b. Relevant Staff Guidance Documents

1. NUREG-1800, Rev. 1 "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (Sept. 2005) (NRC Staff Exh. 19). This document provides guidance to the NRC Staff reviewers for performing safety reviews of LRAs under 10 C.F.R. Part 54. Particularly relevant to Contention 4 is section 3.0.1 of NUREG-1800 which addresses "Background on the Types of Reviews" in the context of license renewals and discusses the methods that an applicant may use to conduct its aging management reviews, including the option of doing so by satisfying the requirements of NUREG-1800.

2. NUREG-1801, "Generic Aging Lessons Learned (GALL) Report" (Sept. 2005) (NRC Staff Exh. 7; Entergy Exh. E4-05) (GALL Report). NUREG-1801 contains the NRC Staff's generic evaluation of existing power plant programs and documents the NRC Staff's judgments as to where existing programs need to be augmented in order to protect the public during the PEO for a license renewal. NUREG-1801 also articulates the Staff's guidance for FAC. Specifically, section XI.M17 of NUREG-1801 addresses "Flow Accelerated Corrosion" and lays out ten principles that the Staff believes ought to be reflected in a FAC AMP.

In addition to the NRC guidance documents, we note that an industry group, the Nuclear Safety Analysis Center (NSAC) of the Electric Power Research Institute (EPRI), has issued its own guidance: "Recommendations for an Effective Flow Accelerated Corrosion Program" (Aug.

[119] Id. at 1. We note that Mr. Witte's prefiled testimony regarding Contention 4 was challenged in several motions in limine filed before the evidentiary hearing. The Board granted these motions with respect to those sections of Mr. Witte's testimony that addressed the CHECWORKS computer code. However, we denied the motions with respect to those sections of testimony that dealt with factual matters or with configuration management issues. We found that Mr. Witte was qualified to offer testimony in those areas. MIL Order at 7.

2007) (Entergy Exh. E4-07) (NSAC-202L-R3). This document provides EPRI's guidelines for nuclear power plants to implement an effective program to detect and mitigate FAC.

B. Findings of Fact

1. Joint Stipulations

Entergy, the NRC Staff, and NEC have submitted the following two joint stipulations with respect to Contention 4:

> (1) The FAC Program that Entergy proposes to implement during the license renewal period includes the following activities: (a) conducting an analysis to determine critical locations; (b) performing baseline inspections to determine the extent of thinning at these locations; and (c) performing follow-up inspections to confirm the predictions, or repairing or replacing components as necessary.
>
> (2) Section B.1.13 of the License Renewal Application for VY indicates that the VY program for addressing flow accelerated corrosion of steel piping and components is comparable to the program described in the NRC guidance document "Generic Aging Lessons Learned (GALL) Report – Tabulation of Results," NUREG-1801, Vol. 2, Rev. 1 (Sept. 2005), Section XI.M17, Flow Accelerated Corrosion.

Joint Stipulation at unnumbered pages 2-3.

2. Summary of Key Contested Matters

As discussed in greater detail below, in Contention 4, the intervenor has asserted that Entergy's AMP for flow accelerated corrosion (FAC) fails to demonstrate that the effects of aging will be adequately managed. This contention is based primarily on NEC's allegation that the CHECWORKS model that is part of Entergy's FAC Program will not accurately predict FAC at VYNPS for the PEO because the model's algorithms using data from other plants are inaccurate for the recent increase in power at VYNPS and because the model has not been adequately benchmarked for the change in plant parameters associated with the power uprate. The basic issues before this Board are whether Entergy has demonstrated: (1) that the effects of aging from FAC on the intended functions of the piping and components susceptible to FAC will be adequately managed for the PEO associated with the proposed license renewal as required by 10 C.F.R. § 54.21(c)(1)(iii), and (2) that there is reasonable assurance that the

activities authorized by the renewed license will be in accordance with the requirements of the AEA and Part 54, as required by 10 C.F.R. § 54.29.

Prior to addressing the questions presented above, we first establish what is meant by FAC and what processes are included in its definition. As discussed in Part V.B.2.a, we find that the current definition of FAC is restricted to chemical processes that cause pipe thinning, but, as used by NEC, is not limited to chemical corrosion but also includes the process of physical erosion. However, through the plant inspections for FAC and incorporation of this data into the prediction estimates for metal wear, we find that the effects from both chemical and erosion wear are included in Entergy's AMP for FAC. The Board also finds that other causes for metal wear, including droplet impingement and cavitation, are design-related issues that are handled as part of ongoing operations.

To address the first contested issue presented above, we consider whether Entergy has submitted a legally binding AMP for FAC (FAC AMP) in its application, and whether it contains sufficient specificity to meet the demonstration standard required by the regulations. In Part V.B.2.b, we conclude that Entergy's current FAC program for VYNPS (Existing FAC Program) is part of the CLB that is carried forward into the PEO. This includes all modifications to the UFSAR presented in the LRA to address the license renewal period.

The adequacy of Entergy's FAC AMP in demonstrating that the effects of aging will be managed for the PEO is discussed in Part V.B.2.c. As part of this discussion we explore Entergy's reliance on the CHECWORKS computer model in its assessment of FAC, specifically investigating to what degree Entergy uses the results from CHECWORKS in its AMP. Based on the description of the program in the LRA and the testimony presented at the hearing, the Board finds that: (1) Entergy's Existing FAC Program (that will carry into the PEO as Entergy's FAC AMP) is based on NUREG-1801, which, in turn, references the specific requirements of the power industry recommendations presented in EPRI's NSAC-202L; (2) aging management actions are directed by the wall thickness measurements made during the plant inspections at

each refueling outage; and (3) the computer model CHECWORKS is only used as one of several means to select the critical locations for inspections and has a marginal, if any, role in trending wear rates to assess the safety aspects of the plant, or in implementing corrective actions. We also find that the model has not always been updated with current plant measurements, reducing its effectiveness as guidance for the next round of inspections.

To address the second contested issue, we explored whether the CHECWORKS model will accurately predict pipe and component corrosion with the new power levels implemented at VYNPS in March 2006. In Part V.B.2.d, we find that there is no need to re-benchmark CHECWORKS, since the correlations in the model were derived using plant parameters in the data base that bound those present at VYNPS. As a result, there are no indications that CHECWORKS does not provide sufficiently accurate predictions of wear rates to assist in the selection of the inspection points for measuring the actual metal loss in the piping and pipe components susceptible to FAC. However, we also find that the model should be updated in a timely fashion to further enhance the development of future inspection programs.

a. Definition of Flow Accelerated Corrosion

i. Evidence

There are several questions inherent to issues in Contention 4, including: (1) what was covered when NEC alleged that Entergy's FAC AMP was inadequate, (2) whether and to what extent there are other processes which may, and to what extent, cause wall thinning, and (3) to what degree, if any, these processes are also covered by the Existing FAC Program and the FAC AMP proposed by Entergy for the PEO. According to Entergy witnesses, FAC is limited to the chemical dissolving of the protective oxide layer on the interior surface of carbon steel piping and components containing water or water-laden steam. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 2-3 (Horowitz); Tr. at 1470 (Fitzpatrick). They further testified that if left undetected, the thinning of the piping or component may become so severe (usually over a broad area) that it is no longer able to withstand internal pressure, resulting in a sudden rupture rather than a slow

leak. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 3 (Horowitz). As stated by Dr. Hopenfeld, NEC witness, FAC is a slow process. Hopenfeld Rebuttal Decl. Post Tr. 779, at 33. Dr. Horowitz, for Entergy, stated that steels containing appreciable amounts of chromium have been found to be resistant to FAC. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 3.

Mr. Fitzpatrick, testifying for Entergy, claimed that FAC does not include erosion (mechanical wearing of metal in areas of high turbulence). Tr. at 1470-71. Dr. Horowitz added that it does not include droplet impingement (wearing away of metal by the force of high velocity streams of water-drop laden steam which likely results in a finite hole that does not become larger with time) and cavitation (a common hydraulics term referring to the implosion of vapor bubbles – created by a reduction of local pressure – as they are swept into regions of higher pressure). Tr. at 1475-76, 1616-17. According to Dr. Horowitz, erosion is usually associated with local turbulence caused by a disturbance in the pipe and is most often observed with copper and brass components at the entrance to the heat exchangers where turbulence damages the oxide layer of piping components and exposes the bare metal. Tr. at 1477. Droplet impingement and cavitation are localized design issues that are corrected under operational maintenance programs. Tr. at 1473-76

Dr. Horowitz points out that erosion is not the type of attack that would generally damage piping at VYNPS, since the flow velocities required to mechanically remove the oxide layer from carbon steel pipes are much higher than those that occur with a light water reactor such as VYNPS. Tr. at 1477-78. Where it does occur, Dr. Hausler for NEC testified that erosion tends to be more localized than FAC, focused mostly on the limited area of flow disturbance that is causing the turbulence necessary for erosion. Tr. at 1483-84.

While not contesting the definitions of impingement and cavitation, Dr. Hopenfeld testified to a more general definition for FAC as a “physical phenomenon in which metal

dissolution is accelerated by fluid flow."[120] Dr. Hopenfeld stated that he was not an expert on the corrosion process, but that it was difficult for him to separate erosion from corrosion, and there is no acceptable theory for exactly what happens during the erosion process. Tr. at 1479-81. Dr. Hausler testified that erosion "is a dissolution phenomenon that is caused by the local velocity or shear force of the liquid caused by turbulence effects." Tr. at 1483. While seeming to agree that high velocities are not present at nuclear power stations, he went on to confirm that the shear forces needed to cause erosion are present in localized areas of turbulence. Tr. at 1482-84.

Mr. Fitzpatrick acknowledged that erosion was included with FAC 20 years ago, but, with time, FAC has been narrowed to include only the chemical removal of the oxide layer. Tr. at 1470-71. EPRI, the power industry group that commissioned the development of the CHECWORKS computer model, stated in its guidance document NSAC-202L that FAC is sometimes incorrectly called erosion-corrosion, but notes that erosion is not part of the degradation mechanism now considered in their approach to addressing FAC.[121] Dr. Horowitz testified that, in his opinion, FAC is restricted to the chemical corrosion process in order to clarify communication when considering the counter-measures that differ among the various mechanisms that cause metal wear and to have a definition that people can understand and apply. Tr. at 1474. Specifically, he testified that erosion generally results in small pinhole-type leaks, while thinning due to chemical corrosion occurs over a large area and causes widespread damage that can result in a catastrophic failure. Tr. at 1616. Dr. Horowitz pointed out that CHECWORKS only calculates predictions of corrosion associated with the chemical wearing of the steel piping and components and does not consider erosion. Tr. at 1473.

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[120] NEC Exh. NEC-JH_36, Review of Entergy License Renewal Application for Vermont Yankee Nuclear Power Station: Program for Management of Flow-Accelerated Corrosion at 3 (Apr. 21, 2008) [Hopenfeld FAC Report].

[121] Entergy Exh. E4-07/NEC Exh. NEC-JH_38, Recommendations for an Effective Flow-Accelerated Corrosion Program (NSAC-202L-R3) at 1-1, n.1 (Aug. 2007) [NSAC-202L-R3].

Mr. Hsu, testifying for the NRC Staff, agreed with NEC's broader interpretation of FAC, stating that "[f]low-accelerated corrosion is also known as erosion-corrosion. It is corrosive attack accelerated by high velocity flow, either washing away otherwise protective films or mechanically disturbing the metal itself." Hsu/Rowley Decl. Post Tr. 1432, at 3. Mr. Hsu stated that the Staff considered both the chemical and erosion processes that cause a loss of metal in plant piping and pipe components when it reviewed Entergy's AMP for FAC. Tr. at 1486. Recognizing that CHECWORKS only estimates chemical corrosion, Mr. Hsu noted that the FAC Program is focused towards the chemical removal of the oxide layer and that erosion caused by local turbulence is covered by separate management programs using inspections based on the plant's operational experience. Tr. at 1487.

Entergy's LRA states that the Existing FAC Program at VYNPS applies to "safety-related and non safety-related carbon steel components carrying two-phase liquid or single-phase high-energy fluid [more than] 2% of the plant operating time". Entergy Exh. E4-04 at B-47. Mr. Fitzpatrick testified that FAC programs apply to the feedwater systems and all the process steam systems but do not apply to the service water system, which has different aging mechanisms from FAC and is under another program. Tr. at 1496. He also stated that Entergy's Existing FAC Program includes, inter alia, ultrasonic test (UT) measurements of pipe wall thickness at locations susceptible to chemical erosion as determined by several means, including predictions from CHECWORKS, plant and industry experience, and engineering judgment. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 12.

Mr. Fitzpatrick for Entergy and Mr. Hsu for the NRC Staff, each testified that the UT measurements are not able to discriminate between the processes that cause changes in pipe wall thickness with time. Tr. at 1472 (Fitzpatrick), 1510 (Hsu). As such, erosion will inherently be included with chemical corrosion and any other effects when calculating wear rates from the pipeline inspections. Dr. Horowitz noted that, while CHECWORKS algorithms relate to the chemical weathering of the pipe wall, the model has a feedback component, where the plant

inspections are used to calculate a line correction factor that is used to adjust the predictive results to reflect these actual measurements. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 16-18; Tr. at 1453.

ii. Findings

We find that the current definition of "flow accelerated corrosion" is limited to the chemical wearing of carbon steel piping and components containing water or water-laden steam that covers a broad area of piping, which, if left undetected, could result in catastrophic pipe failure. We find that this definition is consistent with the focus of FAC programs, which include predictive modeling based on algorithms used to estimate these chemical processes. For clarifying communications when considering the counter-measures that differ among the various corrosion mechanisms, erosion – the physical wearing of the metal that generally results in localized leaks – is no longer included with FAC and is managed by its own aging program using inspections based on the plant's operational experience. We find that Entergy's Existing FAC Program does not directly track erosion, nor does it address droplet impingement and cavitation – localized design issues that are monitored and corrected under operational maintenance programs.

Having said that, we find there is nothing in Contention 4 that limits its allegations to only the effects of chemical pipe wear. When it reviewed Entergy's AMP for FAC, the NRC Staff considered both chemical corrosion and erosion as causes for a loss of metal in plant piping and pipe components. While chemical corrosion is the predominant mechanism for the flow-related wear of pipes that is being addressed by Entergy's FAC Program, we find that erosion can also contribute to the loss of metal in the piping networks addressed by this AMP. However, we also find that the UT measurements track the total effects of all wall thinning mechanisms, and cannot readily discriminate between the various mechanisms causing pipe wear. We find that Entergy does include the effects of erosion in its FAC Program by including these measurements as an integral part of the FAC Program and incorporating actual wall

thickness measurements into the CHECWORKS model, we find that Entergy does include the effects of erosion in its FAC Program.

b. Legal Foundation for Entergy's AMP for FAC

i. Evidence

We admitted Contention 4 because we concluded that the petitioners had identified sufficient ambiguity in Entergy's AMP related to FAC to meet the requirements for contention admissibility. LBP-06-20, 64 NRC at 193-94. In part, this decision was based on whether Entergy has demonstrated that the effects of aging are managed by merely stating that its program accords with regulatory guidelines contained in NUREG-1801 and, by reference therein, to the industry standards in NSAC-202L-R3, and, if not, what specificity is required to meet this demonstration. Upon review of the testimony, we are also concerned with whether Entergy's FAC AMP is legally binding and enforceable during the PEO. While only section B.1.13 of Appendix B from the LRA was submitted as evidence into the record for this hearing, as part of our review, pursuant to 10 C.F.R. § 2.337(f), we hereby take official notice of LRA section 3.0 and Appendices A and B.[122]

[122] It appears that these important segments of section 3.0 of the LRA were never introduced into evidence herein. This is unfortunate, given that the Board repeatedly adjured the parties that it was their responsibility to present all evidence necessary to support their positions. Tr. at 608-09; Order (Regarding the Record for the Evidentiary Hearing) (Apr 3, 2008) at 2 (unpublished). As the Commission stated: "[T]he responsibility for developing an adequate record for decision is on the parties, not the presiding officer. . . . [T]he parties are responsible for ensuring that there is sufficient evidence on-the-record to meet their respective burdens." Final Rule, Changes to Adjudicatory Process, 69 Fed. Reg. 2182, 2213 (Jan. 14, 2004). The fact that the application is part of the "hearing file" under 10 C.F.R. § 2.1203(b), and may be subject to mandatory disclosure under 10 C.F.R. 2.336 does not change this result nor automatically make it part of the evidentiary record. Hearing files and mandatory disclosures are usually massive – much larger than the subset of documents introduced into evidence during our adjudicatory proceedings.

Although these segments of the LRA were not introduced into evidence, the Board believes in this context they provide factual information susceptible to judicial and official notice under 10 C.F.R. § 2.337(f) and has therefore done so. However, as required by that regulation, and in accordance with Rule 201(e) of the Federal Rules of Evidence, since the Board's decision rests in part on this official notice, any party wishing to controvert the facts officially noticed may do so by filing a motion for reconsideration or an appeal from this partial initial decision.

Section 3 of the LRA contains a summary of a detailed assessment, conducted at a component and structure level, to identify those items that require aging management review (AMR). LRA at 3.0-1. FAC has been identified in this section as one of those issues. Id. at 3.1-4. The appendices to the LRA contain a description of Entergy's FAC programs. Appendix A presents new information required by 10 C.F.R. § 54.21(d) relating to the AMP for FAC that supplements the updated final safety analysis report (UFSAR) for VYNPS. The supplement to the UFSAR, presented in section A.2 of Appendix A, contains a summary description of the program and activities for managing the effects of FAC aging for the renewed operating license. Specifically, Entergy's FAC AMP for the PEO is described in section A.2.1.14.

As stated therein, the AMP for FAC at VYNPS applies to all carbon steel components carrying water and water-laden steam more than 2% of the time. Id. at A-15. It goes on to state that the program is "based on" EPRI recommendations for an effective FAC program that "predicts, detects, and monitors FAC in plant piping and other pressure retaining components," including an evaluation to determine critical locations for FAC, initial operational inspections to determine the extent of thinning at these locations, and follow-up inspections to confirm predictions, specifying repair or replacement of components as necessary. Id. Appendix A states that this new information will be incorporated into the UFSAR following issuance of the renewed operating license. Id. at A-1. As a proposed license condition, the NRC Staff would require Entergy to include this UFSAR supplement, called for in 10 C.F.R. § 54.21(d), in the next UFSAR update, as mandated by 10 C.F.R. § 50.71(e), following issuance of the renewal license. See FSER at 1-12.

Appendix B of the LRA discusses the Existing FAC Program being used at VYNPS, lists it as a program credited in Entergy's integrated plant assessment (IPA) for managing aging effects for FAC, and states that Entergy's Existing FAC Program is the FAC AMP for VYNPS. LRA at B-1, B-4, B-7, B-12, B-47 to B-48. Mr. Fitzpatrick testified for Entergy that the Existing FAC Program at VYNPS was developed in response to the NRC Staff's Generic Letter 89-08.

Tr. at 1508. He testified that Entergy's FAC AMP will be identical to the Existing FAC Program and that it conforms to the EPRI guidelines contained in NSAC-202L. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 11. In addition, Tables B-1, B-2 and B-3 state that the FAC AMP for the PEO is the Existing FAC Program and that this program is "consistent with" the recommended program in section XI.M17 of NUREG-1801 for FAC with no exceptions or enhancements. LRA at B-4, B-7, B-12. The operational experience with the FAC Program is described in LRA section B.1.13, which asserts that this program: (1) "has been effective at managing aging effects," and (2) has "been improved through implementation of lessons learned from operating experience." LRA at B-48. Based on its IPA, Entergy stated that the FAC Program provides reasonable assurance that the aging effects due to FAC will be adequately managed during the period of extended operation. Id.

Entergy conceded that compliance with and incorporation of regulatory guidance by reference could be subject to challenge if raised in a contention, but denies that NEC has raised such a contention here. Entergy Response at 8. The NRC Staff pointed out that the regulations do not indicate the amount of detail that an applicant must provide to meet the demonstration criteria. Staff Response at 10. The Staff posited that it is sufficient for an applicant to state that its AMP is "comparable to" NUREG-1801 in order to demonstrate that the effects of aging will be managed for the PEO. Id. at 13. An applicant does not need to provide a detailed explanation or description of an AMP in its application because the Staff verifies consistency of licensees' AMPs with Staff guidance through its audits. Id. at 14. The Staff audited Entergy's Existing FAC Program and found Entergy's approach to be consistent with the approved regulatory guidance.[123]

As Vermont pointed out, the NRC Staff stated that its review guidance document, NUREG-1800, indicates that it is acceptable for an applicant to reference its AMP to NUREG-

[123] Id. (citing Audit and Review Report for Plant Aging Management Programs at B 3.0.1.2).

1801.[124] Specifically, Vermont noted that section 3.0.1 of NUREG-1800 requires an applicant to ensure that the plant program contains all the elements of the recommendations in NUREG-1801, and that conditions at the plant must be bounded by the conditions for which the NUREG-1801 program was evaluated. Id.

In its FSER, the NRC Staff specifically reviewed Entergy's claims regarding its Existing FAC Program and found that all the program elements conform to the criteria in the NUREG-1801, AMP XI.M17, and that corrective actions and the 2004 modifications for the power uprate have been effective in managing FAC at the plant. FSER at 3-16 to 3-17. The NRC Staff also stated that Entergy's FAC AMP is defined in the UFSAR supplement (section A.2.1.14) and determined that it is an adequate summary description of the program as required by 10 C.F.R. § 54.21(d). Id. at 3-17. Based on this review, the Staff found that all program elements are consistent with NUREG-1801, and concluded that Entergy had demonstrated that the effects of aging for FAC of carbon steel piping will be adequately managed so that the intended function(s) will be maintained consistent with the CLB for the PEO. Id.

Entergy's corporate commitment to addresses FAC and the details of its corporate program were presented as Entergy Exh. E4-06. Mr. Fitzpatrick testified that Entergy's corporate program was developed in response to the NRC Staff's Generic Letter 89-08 and opined that every plant is required to implement this program. Tr. at 1508. The corporate program provides the requirements for FAC programs for Entergy's nuclear power plants and standardizes Entergy's approach to mitigating FAC damage. Entergy Exh. E4-06 at 3. It presents a systematic approach for long-term monitoring of affected FAC components and provides criteria and methodology for selecting components for inspections, performing those inspections, evaluating the data, and, if necessary, repairing and replacing the piping. Inspection locations are determined by several methods, including results of the CHECWORKS

[124] [Vermont] Response to Entergy and NRC Staff Brief on Pre-Trial Legal Issues (July 15, 2008) at 5 [Vermont Response Brief]; Staff Response at 13 (citing NUREG-1800 at 3.0.1).

model, industry/utility/station experience, and engineering judgment. Id. Mr. Fitzpatrick asserted that the corporate program provides the requirements that must be implemented for Entergy's fleet of nuclear power plants for establishing and maintaining an effective FAC program to help mitigate FAC damage. Tr. at 1508. It includes, inter alia, the detailed responsibilities of the manager, supervisor, FAC engineer, design engineer, and maintenance supervisor. Entergy Exh. E4-06 at 10-14.

ii. Findings and Conclusions

To assist in addressing this issue, the Board investigated whether Entergy affirmatively committed to continue its Existing FAC Program into the PEO as its FAC AMP, whether this commitment is legally binding on the Applicant, and whether there are sufficient details in the program to demonstrate that the effects of aging are adequately managed for the PEO. Through testimony and documentation in Tables B-1 and B-2 of the LRA, we find that Entergy's proposed FAC AMP consists of the Existing FAC Program at VYNPS. As a commitment included in its FSAR, we conclude that as a matter of law Entergy's Existing FAC Program (that already includes changes associated with the power uprate as part of its CLB) carries forward into the PEO.[125] We find that the LRA confirms this conclusion by stating that the Existing FAC Program will be incorporated as an AMP into the UFSAR for the license renewal period. LRA at A-1, A-15, B-4, B-7.

Regarding any changes for the PEO, the NRC Staff's first proposed license condition would require the UFSAR supplement be included in the next UFSAR update as required by 10 C.F.R. § 50.71(e), following the issuance of the renewed license. FSER at 1-12. In summary, we conclude that the presence of Entergy's Existing FAC Program in the CLB and modifications to it presented in the UFSAR supplement in the LRA as documented in Appendix A of the LRA is a legally binding commitment to extend the Existing FAC Program into the PEO.

[125] This finding is in accordance with the definition of the CLB found in 10 C.F.R. § 54.3(a).

Having determined that Entergy's FAC AMP is legally binding, we turn to the question of whether it meets NRC Staff and industry guidelines. Entergy's and the NRC Staff's main arguments are that the AMP for VYNPS is consistent with NUREG-1801 and therefore demonstrates the adequate management of aging. While Entergy agrees that incorporation of regulatory guidance by reference is subject to challenge if raised in a contention, we disagree with Entergy's claim that NEC has not raised such a contention here. By challenging the adequacy of the AMP, NEC does challenge the proposition that the mere reference to NUREG-1801 as the sole support for the AMP does not adequately meet the demonstration standard required of 10 C.F.R. § 54.21.

The description of VYNPS's FAC Program presented in section B.1.13 of the LRA simply states that the FAC Program at VYNPS "is comparable to the program described in NUREG-1801, Section XI.M17," with no other details provided therein. While this Board agrees that some special weight should be given to some NRC guidance documents, the same does not apply to EPRI guidance documents. Further, we reject any suggestion that NRC guidance is on par with NRC regulations (which are legally binding). The regulations require that an applicant "demonstrate that . . . the effects of aging . . . will be adequately managed." 10 C.F.R. § 54.21(c)(1)(iii). The fact that Entergy relies on NUREG-1801 for the details of its AMP is a significant but not the sole factor in our consideration of whether this demonstration has been met. Specifically, section 3.0.1 of NUREG-1800 requires that an applicant ensure that the plant program contains all the elements of the recommendations in NUREG-1801 and that conditions at the plant must be bounded by the conditions for which the NUREG-1801 program was evaluated.

We find that Entergy's reference to NUREG-1801 is not sufficient by itself to meet 10 C.F.R. § 54.21. Specifically, an AMP which consists solely of the bald statements that it is: (1) "comparable to the program described in NUREG-1801," (2) "consistent with the program described in NUREG-1801," and (3) "based on EPRI Report NSAC-202L-R2

recommendations," LRA at B-47, simply does not satisfy the requirement that an applicant actually "demonstrate" that its AMP will adequately manage aging during the PEO as required by 10 C.F.R. § 54.21(c)(1)(iii) or 54.21(a)(3). An unsupported declaration of compliance is not a demonstration of compliance.

Furthermore, Entergy's statement that the AMP is "comparable" to NUREG-1801 does not come close to ensuring that Entergy will comply with NUREG-1801. Any AMP program, however adequate or inadequate, could be said to be "comparable" to the NUREG-1801. The next statement in Entergy's FAC AMP – that it is "consistent" with the program described in NUREG-1801 – also is no guarantee or solution. The simple fact is that NUREG-1801 does not contain an AMP, since it merely consists of two pages briefly describing the characteristics of a FAC AMP and specifies ten "evaluation and technical basis" criteria to be used in evaluating a FAC AMP. Entergy Exh. E4-05 at XI M-61. An enumeration of the criteria to be used in evaluating a program, is not itself a program. Even if Entergy were to adopt the ten criteria of NUREG-1801 verbatim as its AMP, this would just be a description of what a plan should contain, and would not constitute an AMP.

The third statement in Entergy's FAC AMP is that it is "based on EPRI Report NSAC-202L-R2," an industry monograph entitled "Recommendations for an Effective Flow Accelerated Corrosion Program." LRA at B-47. NUREG-1801 says that an acceptable FAC AMP "relies on implementation" of EPRI Report NSAC-202L-R2. Entergy Exh. E4-05 at XI M-61. The EPRI report describes, inter alia, the elements of an effective FAC program, suggests procedures and documentation that will be needed, provides recommendations for FAC tasks, and describes the need for a long-term FAC strategy. Regardless of the technical merits or value of the EPRI recommendations, a FAC AMP that merely states that is "based on" the EPRI report is not a demonstration of an adequate AMP because (1) the phrase "based on" leaves huge ambiguity as to what the FAC AMP actually consists of, and (2) the EPRI report is a set of recommendations and is not itself an AMP.

While the use of the term "comparable" in the LRA is an insufficient demonstration, we note that the LRA went on to state that Entergy's AMP is a "program consistent with NUREG-1801." While this consistency by itself does not appear to be a guarantee that all aspects of the NUREG-1801 program will be adhered to, it is clear from Table B-3 of Appendix B of the LRA that this phrase is one of three relative terms used to describe the comparison between VYNPS's program and the corresponding description in NUREG-1801 – the others being "programs with enhancements" and "programs with exceptions to NUREG-1801." In this context, being consistent with and having no exceptions to NUREG-1801 provides a greater level of assurance of the identity between Entergy's FAC Program and the program description provided in NUREG-1801.

We turn to other evidence to determine whether or not there are sufficient details in VYNPS's FAC AMP program to demonstrate that the effects of aging will be adequately managed during the PEO. As a starting point, we find that the term "demonstrate" in 10 C.F.R. § 54.21 is a strong, definitive verb that logically requires an applicant to provide a reasonably thorough description of its AMP to show conclusively how this program will ensure that the effects of aging will be managed for its specific plant. For an applicant to just illustrate how its proposed program will, or promises to, follow the same generic program recommendations provided to all plants does not clear the bar required by the regulations. To claim otherwise would imply that the AMP has already been generically developed for all plants and would render 10 C.F.R. § 54.21 unnecessary.

We recognize that NUREG-1801 was developed by the NRC Staff at the direction of the Commission to provide a basis for evaluating the adequacy of AMPs for license renewals. NUREG-1801 at 1, 4. Surely the need to provide some guidance to an applicant in interpreting how to demonstrate that the effects of aging are being managed is a worthwhile effort that, as the Staff pointed out, has, in part, been achieved through the publication of NRC guidance documents. Staff Response at 10-12. However, the primary benefit of these guidance

documents is to reduce the workload, not to be inclusive of all the requirements that must be met by an applicant in regards to aging management for FAC.

As the NRC Staff correctly pointed out, the regulations do not indicate the amount of detail that an applicant must provide in describing its AMP to meet the demonstration criteria. We find that if an applicant submits an AMP that shows how it addresses the recommendations of NUREG-1801, then it will have provided the demonstration required of 10 C.F.R. § 54.21. By providing the goals of an acceptable aging program for FAC in NUREG-1801, the Commission and the Staff have eliminated much of the uncertainty in this subjective requirement.

But we find that an applicant promising to prepare a program in the future consistent with NUREG-1801 or merely stating that its AMP meets NUREG-1801 without any specificity falls short of the required demonstration, since section XI.M17 of NUREG-1801 consists of less than two pages of narrative evaluating EPRI's guidelines presented in NSAC-202L-R3 with an absence of plant-specific details. While it is reasonable to say that adherence to these recommendations and guidelines in developing a plant-specific program will result in demonstrating that the effects of aging are adequately managed, whether an applicant is successful depends upon whether it is has shown that the specific plant details of its AMP have adequately addressed this guidance. But a bald reference to NUREG-1801 fails to show how the recommendations of NUREG-1801 are proposed to be implemented for VYNPS and does not demonstrate that the effects of aging are adequately managed for the plant.[126]

For Entergy's LRA, the details of its proposed FAC AMP are found in its corporate program (Entergy Exh. E4-06) as reflected in its Existing FAC Program that will continue into the PEO, as described in the next section. Based on the information in the LRA and subsequent

[126] The fact that the Commission has stated that the use of an AMP identified in NUREG-1801 constitutes reasonable assurance, see Amergen Energy Company, LLC (Oyster Creek Nuclear Generating Station), CLI-08-23, 68 NRC __, __ (slip op. at 6) (Oct. 6, 2008), does not mean that an AMP that consists solely of a bald statement that it is "comparable to," "based on," or "consistent with" NUREG-1801 provides such reasonable assurance or "demonstrates" that aging will be adequately managed.

testimony, this Board finds that Entergy's corporate program (Entergy Exh. E4-06) does implement the recommendations of NUREG-1801, as well as the more detailed guidelines provided in EPRI's NSAC-202L-R3.[127] Comparison of the corporate plan with the recommendations in NUREG-1801, and, in turn, with the program details described in NSAC-202L-R3 indicates that the proposed AMP does conform to the recommendations presented in the Staff guidance and industry document. While plant-specific details are not available to this Board, the details provided by Entergy's corporate program and the specific requirements described in NSAC-202L-R3, provide sufficient demonstration to this Board that the effects of aging will be adequately managed for the period of extended operation at VYNPS. We find that there is sufficient specificity to show that the industry guidelines required by NUREG-1801 have been implemented at VYNPS.

c. Adequacy of FAC AMP in Demonstrating Aging Management

To address the adequacy of Entergy's FAC AMP, we reviewed the applicant's description of its Existing FAC Program, explored the details of its inspection plan, evaluated the role of CHECWORKS in its AMP, and investigated the timeliness of Entergy's updates to CHECWORKS with plant specific data. Each of these topics is discussed below.

[127] Furthermore, it is clear from Table B-3 and the description of the program in section B.1.13 of the LRA that the FAC Program meets the requirements of NUREG-1801 with no exceptions or enhancements.

i. Evidence

1. FAC Program description

To resolve portions of Contention 4, we inquired into the details of VYNPS's Existing FAC Program. As previously established, Entergy's Existing FAC Program will be carried into the license renewal period as its FAC AMP. As such, testimony relating to the existing program, by extension, also relates to Entergy's proposed FAC AMP. Unless specifically designated otherwise, reference hereafter to Entergy's FAC Program relates to both the existing program and the proposed AMP for FAC.

As previously mentioned, the Existing FAC Program was developed in response to the NRC Staff's Generic Letter 89-08 to monitor metal wear in carbon steel piping and pipe components containing single phase (i.e., water) and two-phase (i.e., water-laden steam) high energy fluid more than 2% of the time. Tr. at 1508. For Entergy, Mr. Fitzpatrick testified that the VYNPS FAC Program primarily applies to single phase piping, since most of the two-phase piping has been converted to FAC-resistant material. Tr. at 1675. Dr. Horowitz testified for Entergy that "[a]s defined, FAC only attacks carbon steel components in the presence of purified flowing water or wet steam. It does not attack steels containing other fluids, such as oil. . . . [or] steels containing appreciable amounts of chromium." Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 3. Mr. Fitzpatrick testified that CHECWORKS was also applied to low-alloy steel (i.e., metal with less than 1¼% chromium content, Entergy Exh. E4-07 at 4-3), and that subsequent inspections did not detect any wear at these locations. Tr. at 1537-38.

In terms of the details of the FAC AMP, it is noted that all parties stipulated that, during the PEO, Entergy proposes to implement the following activities: (1) conducting an analysis to determine critical locations; (2) performing baseline inspections to determine the extent of thinning at these locations; and (3) performing follow-up inspections to confirm the predictions,

or repairing or replacing components as necessary.[128] The effect of the recent EPU on Entergy's FAC analysis for the plant has been reviewed by the NRC Staff in its safety evaluation,[129] and, as Mr. Hsu and Mr. Rowley testified, the NRC Staff concluded that Entergy adequately addressed the effect of the changes in the plant operating conditions on the FAC analysis. Hsu/Rowley Decl. Post Tr. 1432, at 6.

Dr. Hopenfeld for NEC contested the engineering assumptions underlying Entergy's FAC Program and, through the current program's extension into the PEO, Entergy's FAC AMP. His challenges related to the adequacy of CHECWORKS in addressing the increased power level during the PEO. Hopenfeld Decl. Post Tr. 779, at 11-12. Mr. Witte, also testifying for NEC, concluded that the FAC Program is not in compliance either with the plant's CLB and EPRI guidance from about 1999 through February 2008 for failure to timely update CHECWORKS with the plant-specific data and the need to benchmark the model with the new plant conditions at the uprated power level.[130]

Mr. Fitzpatrick stated that, as part of its FAC Program, Entergy has selected the computer model CHECWORKS to perform the predictive analysis required by NUREG-1801 and, by reference, EPRI's NSAC-202L-R3. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 11-12. He said that CHECWORKS was selected because of its industry-wide acceptance. Tr. at 1547-48. As discussed in greater detail below, the results from this model are used as one of five methods to select the locations for plant inspections. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 12. Mr. Fitzpatrick stated that the trending of FAC wear on piping is not based on the results from CHECWORKS but on the actual inspection data. Id. at 48-49. He also stated that the

[128] Joint Stipulation at 2-3; Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 10.

[129] See NRC Staff Exh. 14 at 17 (VYNPS EPU SER § 2.1.6).

[130] NEC Exh. NEC-UW_03, Evaluation of Vermont Yankee Nuclear Power Station License Extension: Proposed Aging Management Program for Flow Accelerated Corrosion (Apr. 25, 2008) at 4-10 [Witte FAC Report].

actual wear rates are one of the five criteria mentioned above that are used to select components for subsequent inspections. Tr. at 1649.

Mr. Fitzpatrick testified that while the FAC Program is not designed to detect and monitor erosion, the FAC inspections described in more detail in the following section will detect pipe wall thinning regardless of the cause. Tr. at 1472, 1701. Likewise, he stated that other programs manage the aging of piping systems not within the scope of the VYNPS FAC Program and would address potential erosion issues. Tr. at 1473. Dr. Horowitz testified that inspections to check for mechanical damage are selected by operating experience. Tr. at 1512.

2. Inspection program

Mr. Fitzpatrick testified that the FAC Program includes plant inspections of piping and components during each refueling outage. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 12. He stated that the items to be inspected and the locations of these inspections are selected in consideration of five factors: (1) required re-inspections and recommendations from previous outages, (2) CHECWORKS susceptibility rankings or need to calibrate the CHECWORKS model, (3) industry/utility/station experience including items identified through work orders and condition reports, (4) susceptible large bore piping not previously modeled and all small bore program piping, and (5) engineering judgment. Id. Mr. Fitzpatrick testified that currently, approximately one-third of the locations are determined by the results of CHECWORKS, one-third based on previous inspection data, and one-third based on operating experience. Tr. at 1677-78.

Mr. Fitzpatrick stated that piping and components can only be inspected at refueling outages, and, while an inspection is performed every outage, not every pipe is inspected at every outage. Tr. at 1568-69. He added that the specific number of points to be inspected is not designated in the FAC Program but left to the judgment of the FAC engineer and justified in the scoping document for each outage. Tr. at 1575-76. The selection of components for

inspection by the FAC engineer is subject to peer review by another engineer. Tr. at 1649 (Fitzpatrick).

Mr. Fitzpatrick and Dr. Horowitz testified that up to 35 points were measured during each outage prior to the uprate. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 24. In scoping the first three FAC inspections after the power uprate, Entergy included an added measure of conservatism by inspecting 50% more locations to provide further confirmatory data points for the program. Id. at 24-25. Dr. Hopenfeld pointed out that Entergy had not disclosed what fraction of the FAC-susceptible piping in VYNPS is covered by the increased monitoring, making its significance unclear. Hopenfeld Rebuttal Decl. Post Tr. 779, at 33. Regardless, Entergy witnesses testified that little wear had occurred between the uprate in March 2006 and the outage in the spring of 2007 during refueling outage (RFO)-26. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 24.

NSAC-202L-R3 states that the grid size for inspections of large bore piping (i.e., greater than 2" diameter piping) varies with the size of the pipe or component – from 1" grid spacing for up to a 3" diameter pipe to 6" grid spacing for a 24" diameter pipe. Entergy Exh. E4-07 at 4-15. Entergy witnesses testified that the reason for this is that the larger pipes have a greater amount of material that may be lost before they fail, thus allowing for a larger grid size. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 41-42. For individual components like pipe elbows, the entire component is inspected at the grid spacing. Id. at 42.

Mr. Fitzpatrick stated that measurements are made all the way around the pipe and, axially, two-diameters downstream of the selected location. Tr. at 1664-65. If degradation is found, Entergy stated that the grid size is normally made smaller in that area, Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 41, and the grid is extended axially until no wear is found or another component is encountered. Tr. at 1665 (Horowitz). If another component is encountered in that distance, it is also inspected. The extent of the axial measurements for each component varies with the type of component. Tr. at 1667-68 (Fitzpatrick).

Dr. Hopenfeld recommended an axial distance of 25 to 45 pipe diameters beyond any flow disturbance based on the distance generally required for flow to fully develop. Tr. at 1668. Mr. Fitzpatrick testified that VYNPS has done axial inspections on four different lines up to six diameters distance downstream from a component and has not found any excessive wear. Tr. at 1669-71.

Mr. Fitzpatrick testified that pipes that are selected for the FAC Program are chosen in accordance with NSAC-202L. Tr. at 1543. As recommended by EPRI, he agreed that CHECWORKS is not used at VYNPS to predict FAC locations for small bore piping (i.e., less than 2" diameter). Tr. at 1545. Regardless, Mr. Fitzpatrick stated that small bore piping is still part of the FAC Program at VYNPS, including inspections performed at locations associated with disparities found from more than 10 years of plant experience. Tr. at 1531. Mr. Witte however, states that the ranking of small bore piping was not done and, "[w]ith no ranking, the basis for selection of high susceptibility points for small-bore piping is not evident." Witte FAC Report at 19. However, Entergy's exhibits indicate that initial scoping for small bore piping was performed as early as 1992 as evident by the scope and criteria presented in the FAC Program documents. Entergy Exhs. E4-41 at 2, E4-42 at 2.

Mr. Fitzpatrick stated that to perform FAC inspections, the grid is painted on the pipe or component, and measurements are made based on this grid to determine wall thickness. Tr. at 1562, 1664. Rather than recording at specific grid points, Mr. Fitzpatrick stated that Entergy has taken an additional step at VYNPS by scanning the entire area within an individual block of the grid. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 42. By moving the UT transducer over the entire surface, he stated that the lowest wall thickness in the grid square is recorded and that this minimum value is selected as input into CHECWORKS for the entire grid box. Id. Entergy witnesses believe that this technique assures that the thinnest readings in a component are found. Id.

3. Role of CHECWORKS in Entergy's AMP

Mr. Fitzpatrick testified that CHECWORKS is only used in the FAC Program as one of five methods to assist FAC engineers in identifying potential locations of FAC vulnerability. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 12. Dr. Horowitz, the coauthor of CHECWORKS, stated that the plant pipe network is divided into a number of analysis lines with the same operating conditions, including temperature, dissolved oxygen, pH, and flow rate. Tr. at 1550-51. He stated that these lines are entered into the model along with plant-specific characteristics defining flow rate, component geometry, material properties, and steam quality. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 16. Water chemistry, in turn, is calculated at each location in the model from plant-specific inputs defining oxygen concentration in the feedwater and reactor steam effluent, thermodynamic conditions, and flow rates. Id. Dr. Horowitz stated that the model inserts this data with user-defined component geometry into the model correlations to predict the metal wear rate for each modeled pipe length and component. Id.

Dr. Horowitz testified that CHECWORKS uses two types of evaluations in determining the susceptible locations for FAC and predicting wear rates. Id. at 17-18. He stated that the first evaluation, called a "Pass 1 Analysis", is conducted to report predicted wear rates based only on plant operating characteristics that do not incorporate actual pipe thicknesses from plant inspections. Id. at 17. This evaluation is normally used by the FAC engineer to generate a list of components for inspection when plant data are not available. Id. Once plant inspection data became available, Dr. Horowitz stated that the second evaluation, called a "Pass 2 Analysis", incorporates measurements from these inspections. Id. at 18. The model then compares the results to the initial predicted values and adjusts the FAC calculations to account for actual wall thickness through the use of a "line correction factor" (LCF). Id.

NUREG-1801 states that CHECWORKS provides a bounding analysis for FAC that results in reasonable assurances that structural integrity will be maintained between inspections. Entergy Exh. E4-05 at XI-M-61 to XI-M-62. Dr. Horowitz testified that the

prediction correlations were initially based on FAC laboratory testing in France, England, and Germany, and from plant operational data from Germany. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 18-19. To refine the accuracy of the CHECWORKS predictions, the model was subsequently revised with a larger data base of actual inspection results from U.S. operating plants. Id. at 19.

Mr. Fitzpatrick testified that he did not see any increase in wear rates from the 2007 inspection, the first RFO after the power uprate in March 2006. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 24; Tr. at 1676. Dr. Hopenfeld suggested that there may not have been sufficient time for the effects to be measurable in this short time frame. Tr. at 1688-89. However, Mr. Fitzpatrick noted that all the predictions made by CHECWORKS at VYNPS have been conservative in that all measurements have shown less wear than predicted by the model. Tr. at 1596. He went on to testify that Entergy historically increased the measured wear rates by 10% to assure that the model would conservatively over-predict corrosion, Tr. at 1533, and further increased this safety margin to 25% during the EPU to account for the increased power level. Tr. at 1684.

As previously mentioned, CHECWORKS is used to assist FAC engineers in identifying potential locations of piping and components susceptible to FAC. Mr. Hsu testified that, for piping without inspection data, CHECWORKS selects the most susceptible components in a line or a section of piping for inspection. Hsu/Rowley Decl. Post Tr. 1432, at 4. He added that for piping that has previously been inspected, CHECWORKS is used to select the components that have the highest wear rate and lowest failure time for inspection. Id.

Dr. Horowitz stated that CHECWORKS is "not used for nuclear design or nuclear applicability but just to provide information to FAC engineers." Tr. at 1600. As he stated, "CHECWORKS doesn't find the problem, but operating experience does." Tr. at 1512. While the use of a numerical model like CHECWORKS is recommended by NUREG-1801 and NSAC-202L-R3, both Mr. Fitzpatrick, who was the prior FAC engineer at VYNPS, and Dr. Hopenfeld,

NEC's expert, conclude that the FAC Program would not be materially affected if CHECWORKS was not included in the AMP. Tr. at 1678 (Fitzpatrick), 1690 (Hopenfeld). Dr. Horowitz, co-author of the model, also testified that once the plant conditions have stabilized and correlated with measured wear rates from the plant, continual use of CHECWORKS provides very little additional benefit to the FAC program. Tr. at 1696. "CHECWORKS adds value when conditions are changing, you want to forecast what impact it has on corrosion." Tr. at 1696. He went on to state that NSAC-202L-R3 recognizes this in their recommendation that half of the inspections done during a refueling outage should be new locations. Tr. at 1696.

4. Updating CHECWORKS with Inspection Data

Mr. Witte testified that Entergy has not consistently updated the model with plant inspection data as required by its Existing FAC Program and, by not keeping it current, suggested that "susceptible locations may not have been inspected during this time period." Witte FAC Report at 15. He specifically asserted that Entergy had been derelict by failing to update CHECWORKS during the period from 1999 until fall 2006. Id. at 15-16. Likewise, he testified that as of April 2008, the power uprate design data had not yet been incorporated into the model, which allegedly casts a shadow on the results of inspections during RFO-25 in the fall of 2005 and RFO-26 in the spring of 2007. Id. at 2. According to Mr. Witte, the lapse in updating the model may have significantly weakened the trending and predictive capability of the software, both during the lapse period and presently. Id. at 16. He asserted that the FAC Program was in noncompliance with the CLB because the model has not been updated in accordance with its procedures. Id. at 19. Mr. Witte also testified that, from 2000-2006, VYNPS used an outdated version of CHECWORKS software, and that at least four components in 2004 were predicted to have a wall thickness at that time that was less than the operability limits and "should be considered unsafe with potential rupture at anytime." Id. at 17.

Mr. Fitzpatrick testified for Entergy that all applicable inspection data was incorporated into the model during the summer and fall of 2000, that additional updates were performed for

the feedwater system in 2003, and another update was performed in 2006. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 44-46. While the four inspections performed between 2001 and 2005 showed that the wear rates predicted by the CHECWORKS model were consistently conservative, id. at 44, Mr. Fitzpatrick stated that inspection data from the previous outage was not incorporated into the model in time for scoping the program for the 2005 outage, i.e., RFO-25. Tr. at 1719-20. He pointed out, however, that the inspection planning and component selection for RFO-25 were based in part on the conservatively high wear rates previously predicted by CHECWORKS, which were subsequently confirmed as conservative by the 2006 update. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 44-45. Likewise, the results from the updated model execution did not identify any instance where recommended inspections were not performed. Entergy Exh. E4-31 at 11. Furthermore, Mr. Fitzpatrick added that the last update confirmed that the previously predicted wear rates were conservative, which, when analyzed with a Pass 2 analysis, reduced the predicted wear rates and increased the times to minimum wall thickness. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 45.

Mr. Fitzpatrick testified that updating CHECWORKS was not necessary in order to determine the appropriate scope of the RFO-25 inspection program, and stated that Entergy did not depart from its CLB since there is no specific interval required for entering additional inspection data into the model. Id. at 46-47. He noted that while CHECWORKS was not updated, all the inspections were conducted, the results were compiled and the data was evaluated to derive the trend in component wear rate. Id. at 47. All of these actions, he asserted, were done in accordance with the FAC Program. Id.

Entergy's internal audit in 2004 concluded that "while the [FAC] Program was technically sound, a number of the administrative/documentation issues identified did not meet regulatory requirements" and that the program was "unsatisfactory." NEC Exh. NEC-UW_09 at 2. Mr. Fitzpatrick testified that this conclusion resulted from multiple Condition Reports (CRs) that he wrote for the failure to enter the inspection data into the data management system on time and

for using a draft report in planning for a future inspection because the final report was not issued in a timely manner. Tr. at 1585-88. Mr. Fitzpatrick admitted that over the history of the program, up to three years have passed without CHECWORKS being updated. Tr. at 1589. He went on to testify that Entergy's delay in incorporating the wall thickness measurements into the CHECWORKS model was related to resource availability and stated that the CRs were written in order to notify management of the resource needs to complete this task. Tr. at 1719.

Mr. Fitzpatrick stated that it takes a person about two to three months to compile the inspection data, evaluate it, and update CHECWORKS. Tr. at 1576-77. Eventually all the data gets into the model, except for readings less than 0.005" to keep the prediction estimates conservative by not allowing these low readings to bias the results. Tr. at 1572-73. As the EPRI guidance document NSAC-202L-R3 states: "corporate commitment is essential to an effective FAC program" and "[such commitment should include] [p]roviding adequate financial resources to ensure that all tasks are properly completed." Entergy Exh. E4-07 at 2-1. Mr. Fitzpatrick agreed that there are no efficiencies gained in delaying the updating of CHECWORKS, and testified that Entergy now has a FAC engineer who is dedicated to the model updates. Tr. at 1578-79. While he stated that all the data through the last refueling outage, i.e., RFO-26, is now in CHECWORKS, Mr. Fitzpatrick acknowledged the influence that this evidentiary hearing had on the diligence paid in assuring all the data entry is currently up to date. Tr. at 1590.

Mr. Fitzpatrick testified that the CLB incorporated the recommendations of NSAC-202L-R2, Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 47, but industry guidance does not specify a specific interval for model updates, and merely recommends that the plant inspection data be incorporated into CHECWORKS whenever possible to enhance the FAC predictions.[131] Based on this, he stated that there are no quantitative requirements in the CLB addressing the

[131] Id.; Entergy Exh. E4-33, Recommendations for an Effective Flow-Accelerated Corrosion Program (NSAC-202L-R2) at 4-2 (Final Report Apr. 1999) [NSAC-202L-R2].

frequency to update the model. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 47. While Mr. Fitzpatrick left Entergy employment in March 2008, Tr. at 1717, he said that, if inspection data is not updated in time for the next refueling operation and a pipe is subsequently estimated to reach its critical wall thickness before the following outage, he believed that Entergy would address this issue through its corrective action program, and, if necessary, would include reducing power in order to perform a confirmatory inspection prior to the next outage. Tr. at 1594. He added that CHECWORKS should be updated every cycle. Tr. at 1589. Dr. Horowitz agreed that CHECWORKS should be updated with the plant inspection data after each outage, preferably within 60 to 90 days after each inspection cycle. Tr. at 1718.

Mr. Witte for NEC stated that VYNPS used an outdated version of CHECWORKS from 2000 to 2006 even though EPRI has recommended it update its model as far back as 2000. Witte FAC Report at 17. Mr. Fitzpatrick stated that in 2000, VYNPS updated CHECWORKS from version 1.0D to version 1.0F, and used that version through 2006. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 48. While there are no differences in the model from version 1.0F to 1.0G relating to water chemistry and wear rates for BWRs, according to Mr. Fitzpatrick, Entergy installed the latter version at VYNPS in 2006. Id. Mr. Fitzpatrick stated that the version of CHECWORKS never affected its use as a tool for the FAC Program nor would it have any effect on the implementation during the license renewal period. Id. He testified that the latest version of CHECWORKS was installed at the beginning of 2008. Tr. at 1662-63.

In terms of Mr. Witte's concern about the model predictions for the four components in 2004, Mr. Fitzpatrick pointed out that the predicted time for wall thinning is a numerical calculation performed by CHECWORKS to indicate areas of potential concern and is not based on actual inspection data. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 49. Condition reports are written when the inspection data indicate there is an actual problem with wall thinning based on a measured value. Id. Of the four components highlighted by Mr. Witte, three are composed of FAC-resistant material, and the remaining component was inspected and determined to meet

design requirements with a significant margin. Id.; Entergy Exh. E4-37 at 12 (for component CD30TE02DS).

ii. Findings

As supported by the joint stipulation, we find that Vermont Yankee's FAC Program consists of: (1) conducting predictive analyses using the CHECWORKS numerical model to help determine critical locations susceptible to FAC, (2) selecting inspection locations, (3) performing baseline inspections to determine the extent of thinning at new locations and follow-up inspections to confirm the actual wear rates, and (4) if necessary, repairing or replacing components. The locations for inspections are determined by more than the results from the CHECWORKS modeling, and include consideration of industry/utility/station experience, required re-inspections and recommendations from previous outages, susceptible piping locations not previously modeled, small bore piping program locations, and engineering judgment.

The FAC Program and its use of the CHECWORKS model is primarily designed to track the chemical dissolution of the protective oxide layer of carbon metal piping that generally affects a broad area of piping and components. We find that it is reasonable and prudent to differentiate between the catastrophic pipe ruptures that result from the widespread impacts of FAC and the smaller leaks associated with smaller diameter piping and with localized erosion, droplet impingement, and other causes of metal wear that can be detected and repaired prior to any severe damage. Both Entergy and NEC agree that FAC is a slow process. Based on these facts, we find that Entergy's FAC AMP provides reasonable assurances that the impacts of FAC can be managed in a manner that preserves the integrity of the carbon steel piping and associated components, and that critical leaks from other wear mechanisms will be detected early enough for corrective actions to be implemented prior to catastrophic safety impacts occurring.

CHECWORKS was developed using a common engineering method whereby statistical correlations are created from a large population and are then used to predict behavior for a selected situation using case-specific parameters. Tr. at 1444-48 (Horowitz). Dr. Hopenfeld testified about numerous problems with the fundamental development and application of CHECWORKS, which were documented in the previous section and are specifically addressed in more detail below. Regardless, NEC implicitly acknowledged through the joint stipulation that VYNPS's FAC Program consists of more than just CHECWORKS modeling. NEC did not provide any evidence or testimony that controverted Entergy's position that the CHECWORKS model is only used to select inspection locations and is but one of five criteria used to select the critical areas for FAC susceptibility. As Mr. Fitzpatrick testified, only one-third of the inspection locations were based on the results from CHECWORKS with the majority of the locations selected on the basis of industry/utility/plant experience, past inspections, and engineering judgment. Tr. at 1677-78. He acknowledged that not all the critical grid locations are measured during each refueling outage. Since FAC is a slow process, we find that it is reasonable and prudent not to inspect the same locations during every RFO but to vary the inspection locations during each RFO in order to expand the coverage of piping and components included in the program.

Based on Mr. Fitzpatrick's testimony, we find that Entergy uses the actual plant inspections to decide the need for repairs, while CHECWORKS is used as a planning tool to indicate the location for these inspections. Tr. at 1595. Rather than measuring individual grid points, we find that Entergy scans the entire grid area, recording the lowest reading within each grid block. In addition to helping detect the minimum wall thickness in an area, this technique helps to eliminate some of the variability associated with trying to relocate the instrument over a selected point for each inspection.

We find that CHECWORKS adequately serves its intended purpose by providing one of five methods to select the locations for actual wall thicknesses measurements. However, to be

useful, it seems imperative to update the model with recent plant data prior to planning for the new inspection program to be conducted during the subsequent refueling outage. The Board recommends that the NRC Staff pay close attention to assuring that Entergy's FAC engineer is timely in updating the model with the most recent results. While the co-author of CHECWORKS suggests that the model be updated within 90 days of collecting new data, the Board finds that it may take about 2 to 3 months to evaluate the inspection results and incorporate them into the data base. Given this, it seems more reasonable to require the Licensee to complete this model update within six months after each FAC inspection program is completed.

d. Adequacy of CHECWORKS at VYNPS Uprate Power Levels

To address the adequacy of CHECWORKS at the uprated power levels that now exist at VYNPS, we investigated the benchmarking of the model at the higher power levels, explored alleged deficiencies in CHECWORKS, and reviewed the accuracy and capability of the model to predict FAC. Each of these topics is discussed separately below.

i. Evidence

1. Benchmarking with Increased Power Level

Dr. Hopenfeld testified that the CHECWORKS model will not accurately predict FAC at VYNPS for the PEO because: (1) the model's predictions are insufficient for the recent 20% increase in power at Vermont Yankee, and (2) the model has not been adequately benchmarked for the change in plant parameters associated with this uprate. Hopenfeld Decl. Post Tr. 779, at 11-12. He asserted that up to 16 years of data are needed to provide the data necessary to establish a corrosion rate, Hopenfeld FAC Report at 15-16, and that reliance on the model prior to recalibration could result in improper scope for a FAC inspection. Hopenfeld Decl. Post Tr. 779, at 12. In support of Dr. Hopenfeld's statements, Mr. Witte cited a report apparently prepared by an entity known as the "Petroleum Safety Authority of Norway," which, he stated, supports 5 to 10 years of data for establishing trending for FAC wear rates. Witte FAC Report at 22 (citing NEC Exh. NEC-UW_13 at 28).

Dr. Hausler explained that the location for FAC will change as the flow rate changes and that it will be very difficult to predict where localized corrosion will occur and how fast it will take place with changes caused by the increased flow rate associated with the uprated power level.[132] To benchmark an empirical model such as CHECWORKS, it is his professional opinion that it would take 12 to 15 years to obtain the three data points needed to update all the locations for the increased power level, given that each pipe location or component is not measured every refueling outage. Tr. at 1680-81.

Dr. Horowitz testified for Entergy that CHECWORKS does not need to be re-benchmarked because the model does not change as a result of a power uprate or any other change in operating parameters. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 20. The model was designed to handle changes in plant operating conditions (e.g., thermodynamic conditions, temperature, oxygen concentration, flow rate) as relevant input parameters, which it then uses to calculate the predicted FAC wear under the new conditions. Id. Dr. Horowitz stated that the only thing that changes with the CHECWORKS model when the power level is increased is a change in the plant-specific inputs into the model, and, as a result, he concluded that is not necessary to re-benchmark CHECWORKS when plants have changed operational parameters. Id. at 21.

Mr. Hsu of the NRC Staff agreed that CHECWORKS has been benchmarked using the actual plant data in the model's database, and the user must only calibrate CHECWORKS by incorporating the plant-specific parameters as input into the model to account for the new power levels. Hsu/Rowley Decl. Post Tr. 1432, at 8-9. Mr. Hsu and Mr. Rowley concluded in the safety evaluation of the EPU that Entergy has adequately addressed the effect of the changes in the plant operating conditions into the FAC analysis. Hsu/Rowley Decl. Post Tr. 1432, at 6.

[132] NEC Exh. NEC-RH_03, Discussion of the Empirical Modeling of Flow-Induced Localized Corrosion of Steel under High Shear Stress (Apr. 25, 2008) at 9 [Hausler FAC Report].

Entergy's witnesses testified that with the update of input data for the change in plant-specific parameters, CHECWORKS provides FAC wear rates for the model under the new conditions. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 24. Mr. Fitzpatrick and Dr. Horowitz asserted that the only relevant inputs with the new power levels at VYNPS are the flow rate and temperature, which were updated upon implementation of the EPU. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 20, 46. Dr. Horowitz testified that the differences in wear rates experienced in a power uprate are generally smaller than those experienced by plants where their water chemistry changes. Id. at 21.

In terms of the guidance that Mr. Witte asserts recommends 5 to 10 years of benchmarking, Mr. Fitzpatrick noted that the document discussed the initiation of a condition assessment program where no AMP had previously been in place, and, as such, is not applicable to an established program and does not relate to the use of CHECWORKS at VYNPS. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 27. Mr. Hsu supported this position, and further testified that the reference document credits NUREG-1800 and NUREG-1801 and does not suggest the additional benchmarking for an active FAC program as claimed by NEC. Hsu/Rowley Decl. Post Tr. 1432, at 11.

In addition to the need to benchmark the model, it is Mr. Witte's opinion that the plant data in CHECWORKS can not be compared to VYNPS since only 6 operating plants have increased power by more than 15% and half of these have experienced problems with FAC. Witte FAC Report at 22-23. Dr. Hopenfeld submitted a similar opinion, stating that the 20% power increase in 2006 changed relevant plant parameters including flow velocity and that this will likely result in new areas of high corrosion that the model will be unable to predict since it is calibrated to pre-uprate conditions. Hopenfeld Decl. Post Tr. 779, at 12.

As previously mentioned, Dr. Horowitz contested these allegations, and pointed out that VYNPS is a fairly small plant in terms of power level compared to other units. Tr. at 1659. He stated that the predictive correlations used in CHECWORKS were based on data from

approximately 30 different plants, Tr. at 1658, and flow rates and temperatures from these plants encompass the values at VYNPS at its uprated power level. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 28-29. In addition, there have been 6 plants that have similar uprates in terms of percent of power that have all successfully used CHECWORKS since 2001.[133]

In support of Entergy's position, Mr. Hsu pointed out that the final power level of 1912 MWt at Vermont Yankee is much lower than the original power level at these other plants with power uprates, and that the total increase in power for these other plants is much higher than at VYNPS, since Vermont Yankee started at a lower initial power level of 1593 MWt. Hsu Rebuttal Decl. Post Tr. 1432, at 5-6. He agreed that CHECWORKS was developed considering data from plants operating at much higher power levels than the uprated value at VYNPS, and that FAC is predicted by the model for plant parameters like flow rate and temperature at various power levels, not recognizing whether the power levels are a result of initial conditions or uprated levels. Id. at 6.

Mr. Hsu testified that normally two inspection cycles of data are required for each component to determine the wear rate with new power levels. Hsu/Rowley Decl. Post Tr. 1432, at 10. However, he stated that at VYNPS only one point is needed since the increase in wear rate is directly proportional to the increase in velocity caused by the power uprate. Id. at 12. While only one inspection is required, Mr. Hsu noted that three inspections will be completed prior to the PEO and, after that, inspections will continue throughout the license renewal period. Id. Regardless, as he asserted, CHECWORKS still cannot determine the absolute wear, even with many recalibrations, since corrosion is not an exact science with inherent uncertainties. Id. at 8.

Dr. Hopenfeld contended that changes to hydrogen water chemistry in 2003 have reduced the oxygen content of the plant, which further increased the potential for FAC and

[133] Entergy Exh. E4-09, Declaration of Neil Wilmshurst in Support of EPRI's Opposition to Motion to Compel (Apr. 18, 2008) at 4-5.

justifies the need for benchmarking of CHECWORKS. Hopenfeld FAC Report at 15. He supported this position by citing evaluations performed by Entergy's consultant, Structural Integrity Associates, Inc. (SIA) on environmentally assisted fatigue. Id. (citing NEC Exh. NEC-JH_18 at 3.2). Mr. Fitzpatrick stated that the effects of the hydrogen water chemistry have been incorporated into the CHECWORKS model, Tr. at 1660, and that the change to hydrogen water chemistry did not alter the oxygen concentrations in the feedwater system as demonstrated by measured plant data. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 28 (citing Entergy Exh. E4-18). He testified that Entergy has injected oxygen into the condensate and feedwater lines to establish about 40 ppb of dissolved oxygen to enhance the stability of the iron oxide film on the pipe walls, id. at 15, and, as a result, there has been no drastic change in the oxygen levels with the power uprate. Tr. at 1660. Although, as Dr. Hausler testified, more oxygen may be consumed from the water due to the increased mass transfer, Tr. at 1672, Dr. Horowitz posited that the effect would be small. Tr. at 1673.

2. Deficiencies with CHECWORKS

Dr. Hopenfeld testified that CHECWORKS is not acceptable for predicting FAC because the required inputs to handle the non-linear and local nature of this type of metal loss are not included in the model. Hopenfeld FAC Report at 7. With regard to the localized nature of FAC, Dr. Horowitz agreed that occasionally localized FAC is seen – normally near geometric discontinuities. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 31. However, such local wear usually results in only minor leaks. Id. Dr. Horowitz stated that CHECWORKS addresses turbulence around discontinuities through its use of the geometry factor discussed further herein. Tr. at 1651-52. Mr. Fitzpatrick added that the UT inspections measure the total metal loss from whatever corrosion mechanism has caused it. Tr. at 1472. Dr. Horowitz testified that while none of the algorithms in CHECWORKS are modified by these measurements, Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 19 (citing Entergy Exh. E4-09 at 5), a line correction

factor is calculated from statistical analyses and used to adjust the model results to improve its predictive ability. Tr. at 1654.

Dr. Horowitz testified for Entergy that, unlike erosion mechanisms, as long as the plant operating conditions remain constant, FAC causes metal wear that is linear with time, i.e., a constant rate of corrosion. Tr. at 1690. He stated that this behavior has been demonstrated in numerous laboratory tests and by field measurements matching predictions using the linear algorithm in the CHECWORKS model. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 30-31. Dr. Hausler testified that variations in the surface finish with time could affect the rate of FAC wear. Tr. at 1692. While Entergy did not dispute this, Dr. Horowitz noted that the variation in wear rate with time is very small, and the extent of roughness is not likely to change much more given the existing elderly age of the pipes. Tr. at 1694-95.

In support of the contention that CHECWORKS needs to be benchmarked for the uprated power, Dr. Hopenfeld for NEC claimed that the rate of corrosion varies non-linearly with velocity at exponential powers varying from 2.4 to 6, and that as a result, small changes in velocity can lead to rather large changes in the corrosion. Hopenfeld FAC Report at 4. Dr. Hausler agreed with Entergy that the rate of FAC generally varies almost linearly with fluid velocity, but stated that this linear relationship transitions to an exponential one as local turbulence increases to the degree that erosion becomes a factor in the wear rate. Hausler Rebuttal Decl. Post Tr. 1437, at 2-3. He asserted that whether such transition actually occurs when the flow velocity increased following the power uprate at VYNPS must be determined experimentally. Id. at 3. Dr. Hopenfeld also criticized CHECWORKS for basing the relationship between corrosion and velocity on the dissolution of copper in hydrochloric acid as not being representative of the composition of reactor fluid and piping. Tr. at 1619.

Dr. Horowitz stated that the model uses a nearly linear velocity relationship with mass transfer based on his review of experimental data and plant experience. Tr. at 1626, 1651-53. He quoted several studies whose data, he says, show that for all known geometries, including

straight pipes, bends, and flow restrictions, the dependence of FAC wear rate on velocity is less than unity, i.e., that the increase in wear is less proportionally than the increase in velocity. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 33-34. Dr. Horowitz states:

> The mass transfer correlations built into CHECWORKS are based on laboratory experiments on modeled geometries, published correlations and plant data from many nuclear units, all of which have shown a less than linear relationship exists between velocity and the rate of FAC wear, including velocities higher than those present at VY[NPS] after the uprate.

Id. at 34.

Mr. Fitzpatrick also testified that studies from power plants that have undergone power uprates show that increases in FAC wear rates are proportional to velocity. Tr. at 1697. As a result, it is his opinion, based on actual experience, that the FAC wear rates vary roughly with velocity and do not increase in a non-linear fashion, as claimed by Dr. Hopenfeld. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 34. Dr. Horowitz stated that if the linear relationship incorporated into CHECWORKS was not valid, it would be clear that the model could not track FAC wear rates at the operating plants. Tr. at 1625-26.

An EPRI publication, entitled "Flow Accelerated Corrosion in Power Plants," states that the potential for any local turbulence is addressed through the use of the geometry factors. Entergy Exh. E4-08 at 3-10. As described by Dr. Horowitz, these factors correct for distorted flow that occurs at component disturbances by relating the maximum degradation of a component to the predicted degradation in a straight pipe. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 32-33. CHECWORKS includes over 50 geometry factors to represent various components. Id. at 17. In cases where the component geometry does not match any of those offered in the model, CHECWORKS suggests that a conservative geometry factor be used or that inspections of that component be automatically scheduled. Id. Mr. Fitzpatrick testified that it is his experience that the highest wear rates predicted by CHECWORKS are usually located congruent with components having the most tortuous geometry, and that the effect of geometric

discontinuities does not change with the increased flow rate and temperature associated with the power uprate. Tr. at 1674.

Dr. Hopenfeld testified that the geometry factors used in CHECWORKS were inaccurate because these factors are incorrectly based on the average velocity (both with time and along the cross-section of a component) instead of being based on the local flow velocity value. Tr. at 1620-21. Dr. Horowitz pointed out that nuclear power plants are designed to operate under constant conditions for long periods of time. Tr. at 1651. Under these conditions, he maintained that it is reasonable and appropriate for CHECWORKS to use an average velocity corresponding to the power plant's conditions to represent the localized impacts of FAC. Tr. at 1651.

Dr. Horowitz stated that the copper tests referred to by NEC were not used to establish the wear rates or to define geometry tables, but as an initial, qualitative way to test the effect of different geometries on wear rates. Tr. at 1627. All geometry factors in CHECWORKS come from plant data. Tr. at 1628. Dr. Hopenfeld also stated that the approach used by CHECWORKS in addressing the relationship between local corrosion and total corrosion was based on an inappropriate equation from the EPRI's handbook on FAC.[134] Dr. Horowitz stated that this figure was used as background information in a separate code, but is not used by EPRI and has no relationship to CHECWORKS. Tr. at 1627.

3. Inaccuracy/inability of CHECWORKS to Predict FAC

Dr. Hopenfeld testified that he did not believe that the use of CHECWORKS, or its predecessors CHEC and CHECMATE, has resulted in reduced incidence of FAC failures. Hopenfeld Decl. Post Tr. 779, at 13. While noting that NUREG/CR-6936 reports a 10% reduction in through-wall pipe failures since CHEC was introduced in 1987, he believed this reduction is most likely attributed to increased awareness of FAC by all plants following a

[134] Tr. at 1619 (referencing Entergy Exh. E4-08, Flow-Accelerated Corrosion in Power Plants, Figure 7-2, at 7-8).

catastrophic accident at Surry. Id. He lists numerous examples of failure of CHECWORKS or its predecessors to predict precursors to FAC incidents. Hopenfeld FAC Report at 9-11.

Dr. Horowitz pointed out that the operational experience cited by Dr. Hopenfeld does not indicate any problems with the proper use of CHECWORKS as part of a FAC Program. Horowitz/Fitzpatrick Decl. Post Tr. 1427, at 35-38. He discussed the operating experience cited and its relevance, if any, to the FAC program at VYNPS, concluding that none of these examples involve a case in which the proper use of CHECWORKS was ineffective in preventing an FAC failure. Id. at 38. He and Mr. Fitzpatrick said that the plants referred to by Dr. Hopenfeld either had no FAC program before the accident or their FAC program was not applied to the component that experienced FAC failure, or had a FAC program that did not follow the guidelines in NSAC-202L. Id. at 26.

The accuracy in predicting FAC was questioned by Dr. Hopenfeld and Dr. Hausler for NEC, pointing to the scatter in data presented in the relationships between measured and predicted wear rates as presented in numerous graphs in Entergy Exh. E4-30.[135] While Dr. Horowitz explained that the slow wear rates observed in the feedwater lines at VYNPS contribute to this scatter, he admitted that the small values for the line correction factors from this analysis are outside of the desired range of 0.5 to 2.5 for this parameter. Tr. at 1631. He stated that work is underway to understand the under-prediction of pipe thinning for BWR feedwater systems by CHECWORKS, since they have seen the same behavior at other plants. Tr. at 1631.

While Dr. Hopenfeld was pessimistic of the success of Entergy's FAC Program in predicting FAC, he suggested an alternative that eliminates any computer code, and, instead, dedicates an experienced FAC engineer to this program to help select the critical locations now being done, in part, by CHECWORKS. Tr. at 1610. Mr. Fitzpatrick testified that, VYNPS

[135] Tr. at 1622, 1628-29 (citing Entergy Exh. E4-30 [VYNPS] [FAC] Inspection Program, EPRI CHECWORKS Wear Rate Analysis Results (Sept. 2006) at 57); Hausler Rebuttal Decl. Post Tr. 1437, at 3.

already has a dedicated FAC engineer whose job is solely to maintain the FAC Program and help with the other selection criteria presented in the FAC Program. Tr. at 1578.

Dr. Hopenfeld also proposed that the FAC engineer use a "risk-based" approach whereby all safety-related components subject to FAC will be identified and prioritized into risk-based groups and inspected according to the schedule and varying testing procedures developed for each group. Hopenfeld FAC Report at 15-16. However, he does not indicate how and to what degree this proposed program would be more effective that the current one used at VYNPS.

Assuming CHECWORKS is not abandoned, Dr. Hopenfeld suggested several ways to improve upon the use of the model, including reducing the grid size and modifying some of its equations. Tr. at 1618-19. He asserted that a much denser grid, i.e., a 1" by 1" grid, would help eliminate some of the uncertainties in the model's use and would help address the issue of local turbulence from discontinuities. Tr. at 1687-88. As previously noted by Mr. Fitzpatrick, grid space is based on pipe diameter, for the smaller pipe diameters the grid spacing is as small as 1" and the increase in grid size with a larger pipe is justified on sound technical reasons. See discussion supra Part V.B.2.c.i.2. Regardless of the issues discussed above, EPRI, the owner of the CHECWORKS model, and Entergy recognize that the model cannot fully account for all the potential factors associated with FAC and predict all potential leaks in the carbon steel piping. Entergy Exh. E4-07 at 1-3. Mr. Hsu testified that CHECWORKS cannot determine the absolute wear, even with many recalibrations, since corrosion is not an exact science. Hsu/Rowley Decl. Post Tr. 1432, at 8. As NSAC-202L-R3 clearly states "it will never be possible to prevent all FAC-related leaks and ruptures from occurring." Entergy Exh. E4-07 at 1-3

ii. Findings

NEC contends that Entergy has not adequately benchmarked CHECWORKS for changes in plant parameters and that use of data from other plants is insufficient for the recent

power uprate. Based on the overwhelming evidence provided by Dr. Horowitz, co-author of CHECWORKS, we find that CHECWORKS was benchmarked using an extensive data base of laboratory testing and actual operating conditions from a multitude of plants operating at the same and higher levels than the uprated value at VYNPS.

We find that the CHECWORKS model is designed to handle new operating parameters that change with the uprated power level. At VYNPS, the specific parameters that change, i.e., flow rate and temperature, are supplied as input into CHECWORKS and the model is run to recalculate the new wear rates without the need for re-benchmarking. Even at the uprated power level, this Board finds that VYNPS is a fairly small plant compared to the other units used to benchmark CHECWORKS. We conclude that FAC is predicted by the model for plant parameters, including flow rate and temperature, over a wide range of power levels, and that the model does not recognize whether the power levels are a result of initial conditions or uprated levels. We also find that there is no evidence disputing the fact that the values in the model's data base span the flow rates and temperatures likely present at VYNPS. This provides confidence that the error in the wear rates predicted by CHECWORKS will be in line with the historic experience at U.S. plants. As such, there is no need to benchmark CHECWORKS further, but to merely input the new plant characteristics associated with the power uprate (i.e., flow rate and temperature) and run the model to indicate the critical locations for FAC at the new power level. We find that Entergy has done this and, as a result, has adequately addressed the effects of changes in the plant operating conditions with the power uprate into its FAC analysis.

We also find that the 10 to 15 years of benchmarking proposed by NEC are unreasonable and not defensible in light of the goal of CHECWORKS to merely identify locations for plant inspections. Once a power level is set, nuclear power plants tend to operate at constant conditions for long periods of time. As such, the first inspection made during RFO-26 in January 2007 is reflective of the wear rates for the new power level. Specifically, with the previous inspections establishing the wall thickness prior to the uprate, the new wear rate can

be calculated using the wall thickness measurement made from one cycle of inspection data after the uprate, given that the increased wear rate is directly proportional to the increased flow rate at the uprated power levels.

In addition, we find that there will be three cycles of inspection data to refine the model calibration for the EPU prior to the PEO and that there is no credible evidence disputing Entergy's claim that only the flow rate and temperature have changed with the increased power. While we find that CHECWORKS can be recalibrated with just the RFO-26 inspection, the use of this one data set does not provide any mechanism to evaluate inaccuracies in the measurement readings or in the CHECWORKS algorithms used to predict the critical locations for FAC. Regardless, the results from the two additional inspections that will occur during refueling outages prior to the PEO will provide the data points needed to reduce the variability in the data.

For the new power levels, we do agree that the model should be updated in a timely manner to include the observed wear rates measured during refueling outages so as to better predict the critical locations for FAC. The recent measurements show that virtually no metal loss has occurred at the new power level. NEC is correct in arguing that there may have not been sufficient time for the effects to be measurable in this short period. The results from the two remaining inspections will help to refine the wear rate with increased flow rate at the new power levels. Each update of CHECWORKS improves the estimates of FAC, and better indicates the susceptible locations for future inspections. Furthermore, recalibration does not stop there, but continues with each inspection throughout the operational life of the plant. But, as noted, the effects of the subsequent readings on the critical locations for FAC derived from CHECWORKS are marginal if the plant operates as designed at a constant power level for a long period of time.

We find that historically Entergy has been derelict in updating its prediction model with inspection data. Entergy's delay in updating CHECWORKS promptly after each inspection

cycle due to resource constraints indicates a failure to meet the corporate commitments necessary to have an effective FAC Program. It seriously undermines Entergy's assertion that its Existing FAC Program meets with the requirements of NUREG-1801 and, by reference, NSAC-202L-R3.

To address this issue, we urge the NRC Staff to track diligently Entergy's performance in updating the model to assure that this function is performed in sufficient time to plan for the next inspection cycle. There is no need to cast this request as a mandated license condition given the limited role CHECWORKS plays in the overall FAC Program and the recognition that aging management for FAC could likely proceed unaffected without the use of this model. Furthermore, the requirement for updating the model is implicitly inherent in Entergy's CLB through its commitment to meet NSAC-202L by reference in NUREG-1801.

The Board finds that NEC's alternative "risk-based" approach to the use of CHECWORKS in identifying critical locations for FAC as proposed by Dr. Hopenfeld may not be unreasonable. However, there is no evidence that it is superior to the program developed by Entergy for VYNPS in accordance with the recommendations advocated by NUREG-1801. To some degree, the use of four other criteria besides CHECWORKS to select inspection points may achieve the same results as the "risk-based" approach advocated by Dr. Hopenfeld.

In summary, we find that no further benchmarking is needed since the plant is operating within the range of plant parameters used in benchmarking the model. We find that NEC's experts may be misunderstanding the purpose of CHECWORKS in the FAC Program in their attempt to use continuous benchmarking of the model to predict absolute wear. As confirmed by Entergy and the NRC Staff, this is an impossible goal, which is recognized by the guidance documents for implementing this model. Even so, we find that Entergy's witness, Mr. Fitzpatrick, states that Entergy is committed to input the data from plant inspections to continuously recalibrate CHECWORKS throughout the plant's life.

Regarding the untimely incorporation of inspection data into the CHECWORKS model from 2004 to 2006, we find that Mr. Witte's supposition that the delay in updating the model suggests that susceptible locations may not have been inspected is unfounded speculation. Even though inspection data were not incorporated into the model, we find that the results were compiled and trends in component wear rate evaluated in accordance with the FAC Program. All susceptible piping was identified for inspection independent of the CHECWORKS predictions, and the conservative nature of the previous predictions has been confirmed by the inspection data. We also find that subsequent inclusion of inspection data reduced the predicted wear rates and increased the time to minimum wall thickness. Furthermore, the results from the updated model execution did not identify any instance where recommended inspections were not performed. To help prevent future delays in updating the model, Entergy has hired a new employee as FAC Coordinator whose sole responsibility is to assure that programmatic commitments are met.

While benchmarking is not an issue, we find that the adequacy of CHECWORKS in predicting the critical locations for FAC is debatable. The scatter of data illustrated by the plots of wear rates and the associated under-prediction of wear rates in modeling of feedwater lines for BWRs is persuasive in supporting the claim that CHECWORKS is not effective in calculating and projecting metal loss from FAC. Even given these problems, we find that the potential inadequacy of CHECWORKS does not detract from the effectiveness of Entergy's FAC AMP, given the very limited role that the model has in the overall program, i.e., used only as one of five techniques to estimate the location of the piping and components most susceptible to FAC. We find that the heart of the program lies in the actual UT wall thickness measurements made during each refueling outage – measurements that are not solely dependant on CHECWORKS software or model update. This, combined with the industrial and plant-specific experience gained over the past two decades with FAC, provides for an adequate AMP. As both Entergy and NEC agree, the FAC Program would be effective without the use of the program.

Regarding the other issues associated with CHECWORKS, we find that the model is not intended to be used for erosion, nor is it the goal of the FAC AMP to address this cause of localized metal loss. However, predictions by CHECWORKS inherently account somewhat for erosion and localized turbulence through three mechanisms: (1) by the very nature of UT inspections measuring any form of metal loss, (2) by calculation of a line correction factor to improved the predictive accuracy of the model by correcting for actual measurements, and (3) by the use of geometry factors in the code to evaluate the additional metal wear from turbulence-initiated erosion. We find no merit in NEC's argument that denser grid spacing is necessary at VYNPS to improve accuracy, because the UT measurements at this plant span the entire grid square in search of the thinnest reading, and the minimum value is then assigned to the full square. With this technique, the size of the grid spacing is less important.

We find that FAC wear rates are constant with time, since the variation in wear rates with roughness is small and, given the existing age of the piping, further surface changes are likely to be minimal. Witnesses for Entergy and the NRC Staff have testified that Entergy has determined that an increase in velocities will generally cause proportional increases in FAC wear rates, and this Board agrees. We note, however, that this relationship can transition to an exponential function when the velocity increases sufficiently to cause local turbulence. Regardless, there is no indication that the velocities at the relatively modest power settings for VYNPS would come close to exceeding the transition values. The preponderance of the evidence indicates that wear rates are linear with velocity and, as such, the wear rates should increase proportionately to the increase in power level that occurred in March 2006. Given the small increase in flow rate at VYNPS associated with the relatively small increase in power level with the uprate, it does not appear likely that extensive areas of turbulence have developed at VYNPS to cause significant pipe wall erosion. In addition, we find that the method of scanning the overall grid block rather than just measuring selected grid points and the use of the

geometry factors in the model will help identify these locations for inspection to determine if corrective actions are necessary.

We agree that the CHECWORKS model cannot fully account for all the potential factors associated with FAC, determine the absolute wear (even with many recalibrations), or predict all potential leaks in the carbon steel piping. No one has claimed that it could, and that was never the intended purpose for using this model or for the FAC Program itself. While there is credible evidence that the efficacy of the model may be limited, especially for the feedwater lines, we find that the accuracy of CHECWORKS is sufficient for its intended purpose – being one of five means to select locations for UT measurements during plant inspections.

We also find that the consensus opinion of the parties that the FAC Program could survive without ever using this model is compelling. While Entergy and the NRC Staff have refuted the claims of NEC that incidents of pipe leakage are evidence of CHECWORKS failures, we find that the predictive capability of CHECWORKS is debatable. Having said that, we believe that the model does, in fact, provide useful information that helps ensure that the most susceptible locations for FAC are identified.

C. Summary of Factual Findings Relating to Aging Management for FAC

We find that the term “flow accelerated corrosion”, as used in Contention 4, was not intended to refer solely to the precise definition of FAC relating to the chemical corrosion of carbon steel piping and components, but that it also includes the effects of erosion. Nevertheless, we conclude that Entergy’s Existing FAC Program, and by extension, its FAC AMP for the PEO, includes inspections that measure the effects of both types of metal wear or, indeed, any mechanism that causes wall thinning. This, plus the fact that the effects of erosion on piping and components not susceptible to FAC are covered by other AMPs leads us to conclude that the differences in the definition of FAC are not material to our findings on this contention.

Based on the NRC Staff's conclusions in their 2006 audit, we find that Entergy's Existing FAC Program is indeed consistent with the one described in NUREG-1801 section XI.M17, which, relies on the guidelines of NSAC-202L. However, we also find that the paucity of plant-specific program details found in section B.1.13 of Appendix B in Entergy's LRA falls short of the demonstration threshold required by 10 C.F.R. § 54.21 to show that the effects of aging will be adequately managed for the PEO. Bald statements that an AMP is "comparable to" or "consistent with" NUREG-1801, or that it is "based on" NSAC-202L, do not constitute an AMP, much less a "demonstration" that it is adequate. Nevertheless, we conclude that Entergy's corporate FAC program and Existing FAC Program supply sufficient specificity – including detailed instructions on how inspections should be conducted, how the 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 – to meet the demonstration requirement of 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii).

We find that the specific requirements in Entergy's corporate FAC program, combined with the determination in the NRC Staff's audit that the details of VYNPS's FAC Program adhere to the recommendations of the GALL Report and NSAC-202L, demonstrate that the effects of aging due to FAC will be adequately managed at VYNPS through the PEO. While the FAC Program was never intended to prevent or stop all leaks or ruptures from occurring, see Entergy Exh. E4-07 at 1-3, we find that, based on the results of the IPA as summarized in section 3.0 of the LRA, the use of the existing program as an AMP for the PEO will provide reasonable assurances that the effects of aging will be managed so that applicable components will continue to perform their intended functions consistent with the CLB for the PEO.

We find that Entergy will continue to use CHECWORKS to assist in identifying inspection locations during the license renewal period. We also find that data collected at VYNPS since 1989 and the three sets of data for the 4½ years at the uprated power level prior to entering the

PEO will be sufficient to assure effective use of the CHECWORKS model in the FAC AMP. With the implementation of the FAC program and recalibration of CHECWORKS, we find that there are reasonable assurances that structural integrity of the FAC-susceptible piping will be maintained between inspections – meeting the goal of the FAC Program.

While several other factors were also alleged to contribute to the inability of CHECWORKS methodology to prevent pipe ruptures for unpredicted wall thinning, we find that there is no evidence to suggest that the Entergy's Existing FAC Program and by extension, its FAC AMP are not sound. We also find that, as one tool, CHECWORKS is useful to some degree in helping a plant's FAC engineer select the most critical FAC locations for plant inspections. The effectiveness of CHECWORKS improves if the data from these inspections are entered into the model in a timely fashion, and the model re-calibrated for the observed wear rates. We find that the NRC Staff should ensure that Entergy performs these updates well before each refueling outage, so that the results are available in planning and developing the important plant inspection program.

In summary, we have reviewed all the issues, motions, and arguments presented for this contention and conclude that Entergy has demonstrated that the effects of aging for FAC will be managed for the PEO and that actions with respect to FAC have been or will be taken to reasonably assure that activities authorized by the renewed license for VYNPS will continue for the PEO. Issues, motions, and arguments presented by the parties but not addressed herein have been found to be without merit, unnecessary, or not relevant to the Board's findings on Contention 4.

D. Conclusions of Law

Entergy has demonstrated that its FAC program for the PEO will be effective in managing the effects of aging related to FAC as required by 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii). Since VYNPS's FAC Program adequately assures that the thinning of carbon steel piping and associated components susceptible to FAC will be maintained within ASME code limits, Entergy

has demonstrated that, in accordance with 10 C.F.R. § 54.21(a)(3), the intended functions will be maintained consistent with VYNPS's CLB during the renewal period. Entergy has identified actions that have been or will be taken to provide reasonable assurances that activities authorized by the renewed license will continue to be conducted in accordance with the CLB. The issues related to FAC have been resolved and do not prohibit the NRC Staff from issuing the license on the basis of NEC Contention 4.

VI. CONCLUSION

A. Contentions 2A and 2B

> A. The analytical methods employed in Entergy's 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.
>
> B. Entergy's Second CUFen Reanalysis neither validates the results of Entergy's First CUFen Reanalysis, nor independently demonstrates that CUFens for all components . . . are less than one.

With regard to Contentions 2A and 2B, the Board concludes that Entergy's metal fatigue analyses comply with the legal requirements of 10 C.F.R. §§ 54.21(c)(1) and 54.29, with one significant exception: the use of the simplified Green's function to calculate the metal fatigue on the Vermont Yankee Nuclear Power Station's core spray and reactor recirculation outlet nozzles. In this respect, Entergy's CUFen analyses do not comply with relevant requirements and do not provide reasonable assurance of safety that is required by 10 C.F.R. §§ 54.21(c)(1) and 54.29. These predictive time-limited aging analyses are a condition precedent to issuance of the license renewal. Accordingly, the Board rules that our authorization to issue the license renewal is contingent upon, and the license renewal application cannot be granted unless and until, Entergy completes the confirmatory CUFen analyses on the core spray and reactor recirculation nozzles with satisfactory results without using the simplified Green's function methodology and makes those analyses available for review by the NRC Staff and the other

parties herein. The record will be held open with regards to Contentions 2A and 2B, and Contention 2 will be held in abeyance until 45 days after those events occur.

B. 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.

With regard to Contention 3, the Board concludes, with the proviso noted below, that Entergy has demonstrated that its proposed aging management program for the steam dryer will adequately manage the effects of aging during the 20 year license renewal period, as required by 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii) and that it meets the reasonable assurance standard of 10 C.F.R. § 54.29. In so ruling, we are relying solely on the first branch of Entergy's proposed steam dryer AMP, i.e., Entergy's commitment to continue its existing Steam Dryer Monitoring Program (including GE-SIL-644, Revision 2, which is incorporated therein) during the period of extended operation. The second branch of Entergy's proposed steam dryer AMP, i.e., proposed BWRVIP-139, is subject to multiple contingencies and is not in the evidentiary record, and therefore nothing herein constitutes our reliance on or approval thereof.

Our conclusion that Entergy's proposed steam dryer AMP meets the relevant requirements subject to the mandatory proviso that the renewed license include the following express condition: "Notwithstanding any other provision, Entergy shall continue to perform and implement the continuous parameter monitoring, moisture content monitoring, and visual inspections specified in the AMP, at the intervals specified in GE-SIL-644 Revision 2. These shall continue for the full term of the PEO unless this provision of the license is duly amended."

C. Contention 4

> Entergy's License Renewal Application does not include an adequate plan to monitor and manage aging of plant piping due to flow accelerated corrosion during the period of extended operation.

With regard to Contention 4, the Board concludes that Entergy has demonstrated that its proposed aging management program for the flow accelerated corrosion of plant piping will

adequately manage the effects of aging during the 20-year license renewal period, as required by 10 C.F.R. §§ 54.21(a)(3), (c)(1)(iii), and that it meets the reasonable assurance standard of 10 C.F.R. § 54.29. However, our decision with respect to Contention 4 rests, in part, on certain facts that have been officially noticed under 10 C.F.R. § 2.337(f) and judicially noticed in accordance with Rule 201(e) of the Federal Rules of Evidence, see supra note 122, and therefore any party wishing to challenge such facts may do so by filing a motion for reconsideration with this Board within 10 days, or may file an appeal to the Commission.

VII. ORDER

This partial initial decision resolves Contentions 2A and 2B in favor of the intervenors, NEC and the Vermont Department of Public Services, leaves Contention 2 open and in abeyance, and resolves Contentions 3 and 4 (subject to specified conditions) in favor of Entergy.[136] With the exceptions of Contention 2, 2A and 2B and the opportunity to seek reconsideration of facts officially and judicially noticed, this partial initial decision shall constitute

[136] Pursuant to 10 C.F.R. § 2.1207(a)(3)(iii), the Board, by separate order, is providing to the Commission's Secretary all questions submitted by the parties prior to and during the course of the evidentiary hearing.

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. §§ 2.1212 and 2.341(b). Filing of a petition for review is mandatory for a party to exhaust its administrative remedies before seeking judicial review. 10 C.F.R. § 2.341(b)(1).

It is so ORDERED.

FOR THE ATOMIC SAFETY
AND LICENSING BOARD[137]

/RA/

Alex S. Karlin, Chairman
ADMINISTRATIVE JUDGE

/RA by E. Roy Hawkens for:/

Dr. Richard E. Wardwell
ADMINISTRATIVE JUDGE

/RA by E. Roy Hawkens for:/

Dr. William H. Reed
ADMINISTRATIVE JUDGE

Rockville, Maryland
November 24, 2008

[137] Copies of this order were sent this date by Internet e-mail transmission to counsel for (1) licensees Entergy; (2) intervenors Vermont Department of Public Service and New England Coalition of Brattleboro, Vermont; (3) the NRC Staff; (4) the State of New Hampshire; and (5) the Commonwealth of Massachusetts.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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

CERTIFICATE OF SERVICE

I hereby certify that copies of the foregoing LB PARTIAL INITIAL DECISION (RULING ON CONTENTIONS 2A, 2B, 3, AND 4) (LBP-08-25) dated November 24, 2008, have been served upon the following persons by e-mail (and first class mail) or through NRC internal distribution in this license renewal proceeding.

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[Original signed by Nancy Greathead]

Office of the Secretary of the Commission

Dated at Rockville, Maryland
this 24th day of November 2008