UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3)	)	Docket Nos. 50-247-LR and 50-286-LR

PREFILED REBUTTAL TESTIMONY OF DR. JORAM HOPENFELD REGARDING RIVERKEEPER CONTENTION TC-2 – FLOW ACCELERATED CORROSION

On behalf of Riverkeeper, Inc. ("Riverkeeper"), Dr. Joram Hopenfeld submits the following rebuttal testimony regarding Riverkeeper Contention TC-2.

Q. Please identify yourself.

A. My name is Dr. Joram Hopenfeld and I am a nuclear engineer and currently the CEO and founder of Noverflo, Inc. I prepared prefiled direct written testimony, which included my qualifications and *curriculum vitae*, that was submitted in this proceeding on December 22, 2012.[1]

Q. Please state the purpose of your rebuttal testimony.

A. The purpose of this rebuttal testimony is to respond to numerous assertions, explanations, statements, positions, and claims contained in the testimony of Entergy and NRC Staff's witnesses,[2] and in Entergy and NRC Staff's statements of position,[3] regarding Riverkeeper Contention RK-TC-2. Contention RK-TC-2 concerns Entergy Nuclear Operations, Inc.'s ("Entergy") failure to demonstrate that flow accelerated corrosion ("FAC") will be adequately

[1] *See* Prefiled Written Testimony of Dr. Joram Hopenfeld Regarding Riverkeeper Contention TC-2 – Flow Accelerated Corrosion (December 21, 2011) (RIV000003). I will hereinafter cite to my initial testimony as "Hopenfeld Prefiled Direct."

[2] Testimony of Entergy Witnesses Ian D. Mew, Alan B. Cox, Nelson F. Azevedo, Jeffrey S. Horowitz, and Robert M. Aleksick Regarding Contention RK-TC-2 (Flow-Accelerated Corrosion), March 28, 2012 (ENT000029) ("Entergy's Testimony"); NRC Staff Testimony of Matthew G. Yoder and Allen L. Hiser, Jr. Concerning Riverkeeper Technical Contention RK-TC-2 Flow Accelerated Corrosion, March 31, 2012 (NRC000121) ("NRC Staff's Testimony").

[3] Entergy Statement of Position Regarding Contention RK-TC-2 (Flow-Accelerated Corrosion), March 28, 2012 (ENT000028) ("Entergy's Statement of Position"); NRC Staff's Statement of Position Regarding RK-TC-2 (NRC000120), March 31, 2012 ("NRC Staff's Statement of Position").

managed at Indian Point Generating Unit Nos. 2 and 3 during proposed 20-year extended operating terms, as required by 10 C.F.R. § 54.21(c).

Q. Have you reviewed the testimony of Entergy and NRC Staff's witnesses regarding Contention RK-TC-2 and related statements of position?

A. Yes.

Q. Have you reviewed anything else in preparation of this rebuttal testimony?

A. Yes. In addition to the many documents I previously reviewed as discussed in my initial written testimony, I have reviewed the exhibits appended to the testimony of Entergy and NRC Staff's witnesses relating to Contention RK-TC-2, pleadings related to the contention that were filed after the submission of my initial testimony and expert report, including Entergy's Motion *in Limine* seeking to exclude portions of my testimony and related filings, numerous documents identified by Entergy as relevant to Riverkeeper's FAC contention that were identified and disclosed *after* the submission of my initial testimony, including several additional CHECWORKS modeling reports, and relevant scientific and industry reports. I have used these documents to inform me of the relevant facts and derive my conclusions.

In addition to the documents identified in my initial testimony on Contention RK-TC-2 that were provided as Exhibits RIV000002 through RIV000033 (or which were provided as exhibits by other parties in the proceeding), additional documents that I reference and rely upon in this testimony have been provided as Exhibits RIV000109 through RIV000113, in support of my testimony. To the best of my knowledge, these are true and accurate copies of each document that I referred to, used and/or relied upon in preparing this testimony. In cases where the document was extremely long and only a small portion is relevant to my testimony, an excerpt of the document is provided. If it is only an excerpt, that is noted on the cover of the Exhibit.

Q. Can you summarize your overall reaction to the testimony of Entergy's witnesses regarding Riverkeeper Contention RK-TC-2?

A. My review of Entergy's witnesses testimony indicates that Entergy's FAC program at Indian Point is deficient in various respects. In particular, Entergy's witnesses fail to

demonstrate that Entergy's use of the CHECWORKS computer code at Indian Point is appropriate and in compliance with applicable regulatory guidance. Nothing in Entergy's testimony disturbs my initial testimony and conclusions that the CHECWORKS code at Indian Point produces unreliable, inaccurate, non-conservative results, and that, as a result, fails to adequately detect FAC in susceptible components. Further, though Entergy discusses various "other tools" allegedly employed at the plant, Entergy has failed to provide sufficient details to show that the use of such other methods, in the absence of a quantitative predictive code, will adequately manage FAC at Indian Point. Importantly, Entergy's witnesses fail to meaningfully address the critical safety issues posted by Entergy's inadequate FAC management program. Overall, my review of Entergy's witnesses' testimony has not changed my opinions and conclusions about the adequacy of Entergy's aging management program ("AMP") for FAC at Indian Point: it is inadequate and not in compliance with all relevant standards and regulatory guidance.

Q. Can you summarize your overall reaction to the testimony of NRC Staff's witnesses regarding Riverkeeper Contention RK-TC-2?

A. My review of NRC Staff's witnesses' testimony indicates that NRC Staff has essentially taken Entergy at its word about the adequacy of the FAC program at Indian Point. My review of NRC Staff's hearing submissions did not reveal any independent NRC Staff analysis of key FAC issues at Indian Point, and NRC Staff's witnesses' testimony does not resolve the concerns raised by initial testimony and expert report. Importantly, NRC Staff's approval of Entergy's FAC program appears to be based on the incorrect assumption that CHECWORKS is a predominant feature of the program and used to predict component degradation and to establish inspection intervals, when in reality, Entergy's witnesses now make it clear that CHECWORKS plays a minor role in the program as a ranking tool. NRC Staff's conclusions, thus, do not appear well-founded. In addition, NRC Staff ignores the fact that Entergy's FAC program is fundamentally inconsistent with applicable guidance due to Entergy's use of the CHECWORKS code even though it lacks adequate calibration and produces non-conservative results. Overall, my review of NRC Staff's witnesses' testimony has not changed my opinions and conclusions about the adequacy of Entergy's FAC AMP at Indian Point: it is inadequate and not in compliance with all relevant standards and regulatory guidance.

REBUTTAL TO ENTERGY HEARING SUBMISSIONS ON RK-TC-2

I. Dr. Hopenfeld's Qualifications to Provide Testimony on RK-TC-2

Q. On Pages 2 and 13-15 of Entergy's Statement of Position, Entergy makes statements concerning your experience with FAC issues, including suggesting that you are "not a specialist in the management of aging due to FAC," that you have not "worked directly on FAC program issues," and that your publications are "silent on FAC-related issues." Do you have a response to these allegations about your experience and familiarity with FAC issues?

A. Entergy's various statements questioning my qualifications are completely unfounded, as my education, experience, and extensive knowledge make me well qualified to provide opinions and testimony related to the material degradation phenomenon known as flow accelerated corrosion, or FAC. In particular, evaluating metal degradation by corrosion and erosion that is commonly observed in power plants requires knowledge in electrochemistry, instrumentation, materials and mass transfer, and I have ample educational and professional experience in these fields. This is evident from the information contained in my *curriculum vitae*,[4] which I elaborate on as follows:

The major fields of study I pursued to obtain my Doctorate degree were heat transfer and mass transfer, fluid dynamics, and electrochemistry/electrochemical engineering. My doctoral thesis related to electrochemical machining.

My professional career has involved considerable experience with material/environment interaction, including the following: in the employ of Atomics International, I conducted corrosion and fatigue tests on the effect of flowing sodium on internally heated specimens at high heat fluxes. In the Materials Branch of the Atomic Energy Commission ("AEC") (the predecessor agency of the NRC), I evaluated environmental effects on corrosion, fatigue, and fouling in connection with the development of standards for liquid metal fast breeder reactors ("LMFBRs"), and reviewed and revised standards on coolant chemistry and oxygen monitoring

[4] *Curriculum Vitae* of Dr. Joram Hopenfeld (RIV000004).

for LMFBRs. In the Component Branch of AEC, I managed tests and analytical studies on flow/structure interaction and cavitation damage, a form of fatigue damage. In the Magnetohydrodynamic ("MHD") Division of the Energy Research and Development Administration ("ERDA"), I was responsible for the resolution of issues on erosion/corrosion and instrumentation for high temperature Balance of the Plant Components in fossil fuel steam generators, and I studied manufacturers' data on erosion damage from pin hole leaks in adjacent tubes in Kraft Boilers in relation to pulp and paper plants. While employed at the NRC for 18 years, I evaluated all modes of steam generator tube degradation (including corrosion, high cycle fatigue, wear, and jet erosion), and applicable instrumentation (including eddy current, fiber optics, and acoustics), analyzed the safety consequence of steam generator tube ruptures and other component failures following main steam line breaks (including conducting extensive safety studies on the consequences of tube leaks, such as those formed by erosion in the steam generator under design basis accidents), evaluated the effects of FAC on leak before break scenarios, reviewed NUREG-1570, "Risk Assessment of Severe Accident-Induced Steam Generator Tube Rupture," from the perspective of component aging, conducted an assessment of the safety risk of significant FAC failures inside steam generators following the 1987 Surry Power Station accident, and visited the Sequoyah Nuclear Generating Station to inspect J-tube failures. Notably, while at NRC, I was afforded with knowledge and expertise regarding the use of the CHECWORKS computer model, and CHEC, its predecessor. Lastly, as owner and CEO of Noverflo, Inc., I sponsored and defined the scope of a program of experimental and analytical studies relating to FAC (in, particular, to the feasibility of online remote monitoring of corrosion/erosion) at the University of Virginia, and installed on-line pipe wall thinning monitors at a large copper mine facility in Arizona. In sum, my 45-year career as a nuclear engineer has afforded me with a vast amount of direct, hands-on experience with FAC (that is, erosion/corrosion) related issues.

Entergy's statement that my publications are "silent" on FAC-related issues are simply baseless, as I have published numerous peer reviewed papers that relate to corrosion, wall thinning, and mass transfer modeling, that is, issues that relate to, and are relevant to understanding FAC. As clearly listed in my *curriculum vitae*, these including the following: "Continuous Automatic Detection of Pipe Wall Thinning," ASME Proceedings of the 9th International Conference on

Offshore Mechanics and Arctic Engineering (Feb. 1990); "Experience and Modeling of Radioactivity Transport Following Steam Generator Tube Rupture," Nuclear Safety 26, 286-300 (1985); "Predictions of the One Dimensional Cutting Gap in Electrochemical Machining," ASME Transaction, J. of Engineering for Industry, p.100 (1969); and "Corrosion of Type 316 Stainless Steel with Surface Heat Flux in 1200 Flowing Sodium," Nuclear Engineering and Design, 12; 167-169, (1970).[5]

In addition, I hold two patents related to monitoring wall thinning due to erosion/corrosion, as indicated in my *curriculum vitae*: Method for Monitoring Thinning of Walls and Piping Components 4,922,74 and Method for Monitoring Thinning of Pipe Walls, 4,779,453.[6]

There is simply no credence to Entergy's alleged claim that I do not have specialized knowledge relating to the management of the aging effects of FAC. I clearly possess specialized knowledge in relation to FAC and FAC management processes.

Q. On page 14 of Entergy's Statement of Position, Entergy claims that you "admitted" during the Vermont Yankee license renewal proceeding that you "lack[] expertise" on "the corrosion process." Do you have a response to this allegation?

A. Entergy has lifted a quotation from an Atomic Safety and Licensing Board ("ASLB") decision out of context. In the Vermont Yankee Nuclear Power Plant license renewal proceeding, where I provided expert support for a FAC-related contention, there was an adjudicatory hearing during which corrosion was discussed at length. In particular, an issue discussed in the *Vermont Yankee* proceeding was the degree with which mechanical abrasion plays a part in wall thinning due to erosion-corrosion at high flow rates, an issue that is complex and not well understood. Notably, CHECWORKS was designed in a manner that limits its wall thinning predictions to chemical dissolution only, and the common term, "corrosion-erosion," was changed to FAC, which was defined to include only wall thinning by chemical dissolution; wall thinning involving abrasion of a protective oxide layer either by droplet impingement, bubble collapse or shear forces all affected by flow, are not considered by the computer model.

[5] *Curriculum Vitae* of Dr. Joram Hopenfeld at 4 (RIV000004).
[6] *Id.* at 5 (RIV000004).

In providing its final resolution, the licensing board in the *Vermont Yankee* proceeding deliberated on the various aspects of the definition of FAC, and in this context stated, in full: "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."[7] What I actually stated was that "[i]t doesn't take much to affect the cohesion, to affect the oxide layer. And I am not an expert on oxide layer characteristics and all the details of that."[8] It is based upon this statement that Entergy apparently concludes that I stated I am "not an expert on the corrosion process" and that I "lack[] expertise on an issue central to this contention . . . the physical process associated with FAC."[9] These conclusions are clearly baseless.

As the field of corrosion engulfs numerous disciplines (including electrochemistry, material science, chemistry, and mass transfer), and corrosion involves many varying scientific principles and mechanisms, it is highly unlikely that a given person will be an expert in all aspects of corrosion. A lack of expertise on one particular aspect of corrosion, that is, oxide layer formation and destruction, does not render me unqualified to provide an opinion about FAC-related issues (in particular, the issues relevant to Contention RK-TC-2) with which I have much expertise. As the discussion above makes patently clear, I have a significant amount of education, professional experience, and knowledge related to these issues. I, without a doubt, consider myself an expert on corrosion and the issues raised in Contention RK-TC-2.

Moreover, Entergy misrepresenting my statement in the *Vermont Yankee* proceeding is significant: it demonstrates that *Entergy* lacks the understanding of the underlying assumptions in CHECWORKS. This is very important because Entergy relies on non-technical reasoning to exclude large number of components from the FAC program. In particular, Entergy equating the lack of understanding of oxide layer formation and destruction, to a lack of familiarity with FAC and the corrosion process reflects ignorance of the possibility that actual observed wall thinning

[7] *Entergy Nuclear Vt. Yankee* (Vt. Yankee Nuclear Power Station), LBP-08-25, 68 NRC 763, at 862 (2008).
[8] Official Transcript of Proceedings, Nuclear Regulatory Commission, Entergy Nuclear Vermont Yankee, 50-271-LR; ASLBP No. 06-849-03-LR, Newfane, Vermont, pages 1451-1741 (July 24, 2008), at 1477 (RIV000109).
[9] Entergy's Statement of Position at 14.

may have resulted from a combination of chemical and mechanical forces and, therefore, beyond the predictive capabilities of CHECWORKS.

Q. On page 15 of Entergy's Statement of Position, Entergy claims that a statement made by you in a Declaration submitted in the Vermont Yankee license renewal proceeding, in which you asserted that the issues in that case required specific expertise, "speaks directly to the deficiencies in [your] own testimony, which reflects a lack of specialized expertise in the field of FAC." Do you have a response to this allegation?

A. As evidenced by the lengthy discussion above, as well as by the information contained in my *curriculum vitae*, I undoubtedly have expertise relating to the "very specific and not broadly understood materials, mechanics, energy, and plant operations phenomena beyond the depth of most generalists" that I was referring to in my Declaration in the Vermont Yankee proceeding. As a result, Entergy's statement that I lack specialized expertise is wrong. My previous statement that Entergy refers to does not in any way render my testimony "deficient," since I possess precisely the kind of specialized knowledge that allows me to competently testify about FAC and managing the aging effects of FAC at Indian Point.

II. The Qualifications and Objectivity of Entergy's Witnesses

Q. Pages 1-15 of Entergy's Testimony, as well as pages 15-20 of Entergy's Statement of Position, discuss the educational and professional backgrounds of Entergy's witnesses on Contention RK-TC-2. Do you have any comments on the qualifications of Entergy's witnesses to testify about FAC and Contention RK-TC-2?

A. I have reviewed these portions of Entergy's Testimony and Statement of Position, as well as the *curricula vitæa* of Entergy's witnesses (provided as Exhibits ENT000030 to ENT000033, and ENT000037), and have the following observations:

Mr. Ian D. Mew's *curriculum vitae* does not reflect expertise in mass transfer, nuclear safety analysis, electrochemistry, or materials, which would be demonstrated by technical publications in these fields. While Mr. Alan B. Cox is the engineer responsible for managing license renewal activities at Indian Point, his *curriculum vitae* also indicates that he does not have expertise in

mass transfer, nuclear safety analysis, electrochemistry, or materials, which, again, would be demonstrated by technical publications in these areas. Similarly, though Mr. Nelson F. Azevedo is responsible for implementing American Society of Mechanical Engineers ("ASME") code programs, his *curriculum vitae* does not show that he has expertise in thermal hydraulics, nuclear safety analysis, or electrochemistry, as would be established by technical publications about such topics. A fundamental, in-depth knowledge in all these fields is required to understand the capabilities, limitations, acceptability of CHECWORKS, and to properly assess CHECWORKS' predictions.

I would also like to highlight that as a co-developer of the CHECWORKS computer model and a consultant to the Electric Power Research Institute ("EPRI"), it is my understanding that Dr. Jeffrey S. Horowitz has a direct financial interest in the promotion and use of CHECWORKS at nuclear power plants.

Finally, Mr. Robert M. Aleksick's *curriculum vitae* does not appear to contain any technical publications relating to nuclear safety risk assessment. Furthermore, Mr. Aleksick is the President and founder of a company (CSI Technologies, Inc.) which markets the application of CHECWORKS and is closely affiliated with EPRI and with the development and use of CHECWORKS. As a result, it is my understanding that he also has a financial interest in the use of the CHECWORKS computer model to manage FAC at nuclear power plants.

III. Entergy's Reliance on "Other Tools" Apart from CHECWORKS in the Indian Point FAC Program

Q. Entergy's witnesses testify that "predictions from CHECWORKS normally comprise between one-quarter and one-third of FAC inspections in a given outage" and that only 22% and 20% of susceptible lines are modeled in CHECWORKS at Indian Point Unit 2 and 3, respectively.[10] Do you have a response to these statements?

A. Entergy's license renewal application ("LRA") for Indian Point included an AMP relating to FAC that focused on the use of CHECWORKS as the main predictive tool for

[10] Entergy's Testimony at A76, A77, A94.

identifying specific inspection locations and scheduling inspection intervals.[11] In particular, in its LRA, Entergy committed to control wall thinning from FAC by following the guidance of NUREG-1801, *Generic Aging Lessons Learned (GALL) Report* ("*GALL Report*"), and EPRI's Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L, both of which discuss a FAC management program based upon using the predictive computer code CHECWORKS.[12] The heart of these guidelines was the use of the predictive computer code CHECWORKS to measure FAC-induced wear in susceptible locations and thereby schedule timely inspection intervals at those locations and prevent leaks and ruptures in such risk significant components. My understanding that CHECWORKS was the primary feature of Entergy's FAC program was also based on my review of NRC Staff's final Safety Evaluation Report ("SER") which focused on and discussed Entergy's use of CHECWORKS as a predictive model.[13] Further, most of the information that was disclosed by Entergy and made available for my review related to Entergy's (and predecessor owners') use of CHECWORKS.

The testimony of Entergy's witnesses now presents a very different picture: Entergy has for the first time quantified the degree with which FAC inspections are chosen based upon CHECWORKS, and indicated that CHECWORKS only accounts for a fraction of the overall FAC program at Indian Point. Entergy's witnesses' testimony reveals that CHECWORKS plays a relatively minor role in managing FAC at the plant.[14] Based on my review of Entergy's testimony, it appears that the total CHECWORKS contribution to the FAC program is about 25%, with less than half of that amount being attributed to actual wear predictions and inspection schedules, with the balance to provide relative ranking.

Despite Entergy's apparent relegation of CHECWORKS to a secondary role in the FAC program at Indian Point, the relevant guidelines in the *GALL Report* and NSAC-202L clearly emphasize the use of quantitative predictions of a computer code such as CHECWORKS as the main tool to predict wall thinning and manage FAC. While the guidelines contained in NSAC-202L indicate

[11] *See* LRA at Appendix B § B.1.15.
[12] EPRI, Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L-R3 (RIV000012); *GALL Report*, Rev. 1 at § XI.M17 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 (NYS00147A-NYS00147D).
[13] SER at pp.3-21 to 3-31.
[14] *See* Entergy's Testimony at A72, A76, A77, A84 and A113.

that the use of tools other than a predictive computer model can be applied to components with widely varying operating conditions, the guidelines clearly prefer analytical models over any such other tools. This guidance recommends that wherever possible, a Predictive Plant Model together with thickness measurements be used for FAC predictions, and indicates that other methods may be used only when plant operations vary widely.[15] Furthermore, nowhere in this guidance does EPRI recommend that "other tools" be used to the exclusion of a predictive model. As such, Entergy's clarification that CHECWORKS only accounts for about 25% of the FAC program at Indian Point is inconsistent with applicable guidance specifying that the FAC program must be based on a predictive tool. Of the 25% less than half is actually used to predict wall thinning, the balance is for screening purposes.

In any event, assuming Entergy's characterization of the extent to which CHECWORKS is used in the FAC program at Indian Point is true, Entergy's reliance on CHECWORKS for a quarter to a third of its aging management efforts still renders Entergy's program unacceptably flawed, as this represents a significant percentage of Entergy's program, which, for the reasons discussed at length in my initial testimony, does not adequately address FAC.[16]

Q. Entergy's witnesses testify that a significant amount of FAC-inspection locations are chosen based upon the "trending of pipe wall thickness measurements from past outages,"[17] and that Entergy's reliance on data trending is "entirely independent" of CHECWORKS.[18] Do you agree with Entergy's characterization that the use of trending is independent from CHECWORKS at Indian Point?

A. No, trending is not "entirely independent" of CHECWORKS: reinspections based on actual data in relation to components that were "newly selected" for inspection based upon CHECWORKS predictions, depend upon CHECWORKS in that the scope of components subject to reinspections is necessarily limited by the original CHECWORKS' predictions which resulted in actual inspections. In this regard, Entergy's statement that "[t]he reason a component

[15] EPRI, Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L-R3, at §§ 3.3., 4.4.1-3 (RIV000012).
[16] Hopenfeld Prefiled Direct at 4-7, 9-12.
[17] *See* Entergy's Testimony at 49-50 (for example, explaining that during refueling outages 2R19 and 3R16, reinspections based on trending accounted for 46% of the total number of inspections at IP2, and 67% of total number of inspections at IP3, respectively).
[18] Entergy's Testimony at A72, A77, A79, A80, A95, A96, A97.

was originally selected for inspection is irrelevant."[19] So, while the actual trending calculation may not involve the use of the CHECWORKS code (which, Entergy implies is what I meant in my discussion of Entergy's use of actual inspection data in the FAC program at Indian Point),[20] CHECWORKS' predictive results clearly inform the future use of trending as a "tool" for managing FAC. It is not clear from Entergy's witnesses' testimony how much modeling by CHECWORKS is included in trending or component reinspections.

Moreover, the use of trending measurements *independent of CHECWORKS* at Indian Point fails to comply with the acceptance criteria articulated in *GALL Report*, that "[i]nspection results are input for a predictive computer code, such as CHECWORKS, to calculate the number of refueling or operating cycles remaining before the component reaches the minimum allowable wall thickness."[21] NRC Staff's discussion of Entergy's Indian Point FAC program in the final SER also evinced the understanding that trending measurements are used at Indian Point in connection with the use of CHECWORKS:

> The staff also noted the modeling includes a feature to incorporate actual inspection wall thickness results back into the computer modeling, and that this feature is used to accomplish two important aspects of CHECWORKS™ predictive modeling capability: (1) it permits the user to compare that actual as-found wall component thickness measurements of an inspected component to the wall thickness for the component that was predicted by CHECWORKS™ in the previous modeling results, thus providing a method for confirming the degree of accuracy of the model's previous component wear rate predictions and component wall thickness predictions, and (2) it permits the user to perform re-baselined component wear rate predictions and component wall thickness predictions based on the incorporation of the compiled inspection data for components that are modeled by the computer code and are inspected as part of the applicant's Flow-Accelerated Corrosion Program.[22]

[19] Entergy's Testimony at A95.
[20] Entergy's Testimony at A80.
[21] *GALL Report*, Revision 2 at § XI.M17, p.XI M17-2 (NYS00147A-NYS00147D).
[22] SER at p. 3-28.

Q. Can you provide your opinion about the effectiveness of performing reinspections based upon data trending for managing FAC at Indian Point?

A. I disagree with Entergy's witnesses' testimony that actual pipe wall thickness measurements are useful as a stand-alone tool at Indian Point,[23] and continue to offer my professional opinion that such measurements are only meaningfully useful for preventing unacceptable wall thinning at Indian Point when used in conjunction with a predictive tool. In particular, without a predictive tool, a very large number of points would have to be monitored to assure that the minimum or the critical wall thickness of components at Indian Point will not be exceeded during the proposed periods of extended operation. Because FAC is a local phenomena, and involves variations in local flow velocities and affects a large number of components, an effective and reliable resinspection program would require many inspection points. Notably, as numerous components are in difficult to access areas, it may be difficult to design a reliable resinspection program that is cost-effective; in fact, if it was feasible to inspect, reinspect, and trend the data for every FAC-susceptible point in the plant at frequent intervals, resinspection would be the tool of choice for managing FAC-induced wall thinning. However, Entergy has not put forth any evidence to suggest that a sufficient number of components are monitored and inspected to establish that trending is acceptable as an "independent tool" for managing FAC at Indian Point: while this "tool" consists of taking measurements at some preselected locations, Entergy's witnesses fail to describe what percent of the area out of the total FAC-susceptible area in the plant, is covered by resinspection and how the frequency of inspections is determined, especially in difficult to access locations inside the steam generators. Nor do Entergy's witnesses discuss how the inspection locations are identified, or how the success of the resinspection "tool" is measured, by, for example, providing a comparison of trending measurements with predictions for a statistically significant number of components. Based on the available information I have reviewed, the use of trending at Indian Point appears to be limited to a relatively small number of inspected components. Further, it appears that the use of trending by Entergy is based on the unproven assumption that past wear rate would remain the same in the future, which also limits the usefulness of trending as a tool for managing FAC at Indian Point.

[23] *See* Entergy's Testimony at A94, A96.

Overall, despite the fact that trending is Entergy's apparent tool-of-choice establishing inspection intervals, Entergy's use of component reinspections based on trending was not described in sufficient detail to allow a complete and thorough assessment: Entergy does not address or describe what percent of the total FAC-susceptible area in the plant is monitored by this technique, how often each area is re-inspected, or the accuracy of the predictions based upon this technique. For example, if direct wall thickness measurements and reinspections are used to monitor the feed ring and blowdown lines, Entergy must provide the related data at all high turbulence areas prior to and after the power uprate, but Entergy has not provided such data. Importantly, this "tool" is based mainly on two assumptions: first that the proper location for any given measurement has been identified, and that the wear rate at that location is linear with time. Entergy must demonstrate that these assumptions are valid for all selected locations and the wear predictions agree with actual measurements on a statistically significant number of components. Entergy, and Entergy's witnesses, have not done this. Overall, it remains to be seen that the use of trending will adequately address FAC at Indian Point during the proposed periods of extended operation.

Q. Entergy's witnesses dispute your description of Entergy's use of industry operating experience for selecting FAC in section locations as not necessarily an independent tool.[24] Do you have a response to this?

A. To the extent Entergy relies upon industry operating experience as an independent tool for determining FAC inspection locations, Entergy has failed to provide an adequate description of its meaning. EPRI's NSAC-202L dictates that if tools other than CHECWORKS are used, sample selection must be justified, and Entergy did not provide the required justification. Entergy must provide sufficiently detailed information about how precisely "operating experience" is used to establish inspection schedules and account for changes in plant operating parameters. This is necessary in order to understand the robustness of using "operating experience" to estimate wear rates and predict wall thinning at Indian Point. At the very minimum, Entergy should provide a description of its use of "operating experience" similar to the detail provided about CHECWORKS, as memorialized in NRC Staff's SER.[25] Due to the

[24] *See* Entergy's Testimony at A77, A95, A98.
[25] SER at pp. 3-25 to 3-30.

lack of complete information relating to Entergy's "independent" reliance on operating experience, it is not clear at all that this tool is useful apart from its use in connection with CHECWORKS, or that it will adequately address FAC at Indian Point.

Q. Entergy's witnesses indicate that Entergy relies upon "other inspection programs" and plant activities to select FAC inspection locations, and states as an example that "if a leaking isolation valve is discovered, it would be appropriate to inspect the piping downstream of the leaking valve."[26] Do you have a response to this explanation?

A. Once again, Entergy has not provided enough information in order to assess the effectiveness of Entergy's reliance upon other plant programs and activities to monitor and detect FAC. Entergy has provided nothing quantitative to evaluate, but rather only a brief qualitative description of its use of "other inspection programs." Moreover, in my professional opinion, a properly designed FAC management program would ensure the identification of all high turbulence areas as inspection locations before a leak occurs. The whole idea of proactively identifying inspection location is to prevent leaks, and not use them to identify inspection locations. The fact that *many* leaks occur at Indian Point is only an indication that the FAC program at the plant is ineffective.

Q. Entergy's witnesses dispute your description of Entergy's use of engineering judgment in its FAC program as ineffective, and opine that "the exercise of engineering judgment . . . is a positive aspect of the program."[27] Do you have a response to these statements?

A. Entergy witnesses' discussion of Entergy's use of engineering judgment is qualitative and fails to mention the uncertainties involved in using engineering judgment in selecting specific inspection areas. For example, while the witnesses point out that the feedwater lines were selected for inspection because of their high level of risk, they do not indicate how that risk was calculated, and what models and assumptions were used. Notably, the feedwater line extends into the steam generator and the risk would depend on the specific location along the feedring; in contrast, Entergy's witnesses say nothing about how the frequency of inspection and inspection

[26] Entergy's Testimony at A95.
[27] Entergy's Testimony at A99, A100.

areas are selected.

I continue to offer my professional opinion that Entergy has failed to show that engineering judgment is a sufficiently reliable tool for managing FAC at Indian Point. Notably, nuclear power plant experiences with FAC, such as those that occurred at the Surry and Mihama plants, demonstrated that operator judgments were not sufficiently reliable to protect plant operators from catastrophic accidents. This principle is well recognized throughout the non-nuclear industry where on-line monitoring coupons are commonly used to aid plant operators in monitoring wall thinning. I continue to opine that Entergy has not provided enough detailed information to show that engineering judgment is effectively employed at Indian Point.[28]

Q. Based on your review of Entergy's witnesses testimony about "other tools" (that is, those allegedly separate from CHECWORKS) for managing FAC at Indian Point, has your opinion about the adequacy of Entergy AMP for FAC changed?

A. No. My evaluation of Entergy's "other tools," as discussed by Entergy's witnesses, leads me to conclude that they were not described in sufficient details to allow a thorough assessment of their effectiveness for managing FAC or to draw meaningful conclusions about the validity of their performance. Though these other tools apparently account for 75% of Entergy's FAC inspection program, Entergy's witnesses do not provide a quantitative description of the predictive methodology employed for these techniques.

For example, Entergy's witnesses have not described how many components per outage are inspected by each method, a ranking of component safety significance, the size of the inspection areas relative to all FAC susceptible locations, what percentage of the total FAC susceptible area in the plant is addressed with these other tools, how often the components are inspected, how the frequency of inspections is established, how the validity of the measurements is verified, what the accuracy of the "other tool" predictions' are in relation to actual measurements, or the validity of each method to schedule inspection intervals. Notably, Entergy has failed to show a single comparison of predictions with actual measurements in relation to their "other tools." Further, it appears that the "other tools" identified are subjective in nature and based on personal

[28] *See* Hopenfeld Prefiled Direct at 13-16 (RIV000003).

judgments for selecting inspection areas and assumptions regarding local wear rates and the frequency of inspections. Without detailed information about how these methods are implemented, I cannot form a credible opinion about the risk of major component failures at Indian Point during the proposed extended operating periods. While such information need not be exhaustive, it must be thorough enough to evaluate Entergy's claims. Without the kind of information I've described, it is impossible to determine whether Entergy's FAC program is consistent with the *GALL Report*.

For Entergy to comply with the standard set forth in 10 C.F.R. § 54.21(a)(3), it has the burden of describing its "other techniques" in sufficient detail to assure the public that the integrity of all FAC susceptible components will be maintained between inspection intervals. Entergy has not done this. Until Entergy does this, it cannot rely on "other tools" as a substitute for a reliable predictive software package, as contemplated by applicable guidance. As such, I continue to opine that Entergy does not employ any meaningful tools that, separate and apart from CHECWORKS, would sufficiently manage the aging effects of FAC at Indian Point.[29]

IV. The Performance of CHECWORKS at Indian Point

Q. Entergy's witnesses testify that CHECWORKS "provides a screening and prioritization function," "is designed to provide *best-estimate* wear rates due to FAC" and not a bounding analysis because "CHECWORKS is primarily a ranking tool," and that the model is performing this intended role at Indian Point.[30] Do you have a response to these explanations?

A. To begin with, this appears to be a previously undisclosed explanation of how CHECWORKS functions in the FAC program at Indian Point. This understanding of how CHECWORKS is used at Indian Point is not reflected in NRC Staff's assessment of Entergy's FAC program in its SER.[31] In particular, NRC Staff's discussion in the SER reflects an understanding that CHECWORKS is used as a tool to predict component wall thickness.[32]

[29] *See generally* Hopenfeld Prefiled Direct at 13-16 (RIV000003).
[30] Entergy's Testimony at A36, A102, A103 (emphasis in original).
[31] SER at 3-21 to 3-30.
[32] *Id.*

1

2 More to the point, based on my understanding of applicable regulations and guidance, Entergy's
3 use of CHECWORKS in the manner described, that is, as screening and ranking tool, is
4 unacceptable. In particular, the apparent role of CHECWORKS at Indian Point does not appear
5 to comply with the *GALL Report*, which states that CHECWORKS "is used to *predict*
6 component degradation in the systems conducive to FAC" and that CHECWORKS is acceptable
7 "*because it provides a bounding analysis for FAC*."[33] In addition, the *GALL Report* requires that
8 CHECWORKS be employed to provide an inspection schedule,[34] and this integrally depends on
9 absolute wear rate predictions. The *GALL Report* elaborates that "[i]nspection results are input
10 for a predictive computer code, such as CHECWORKS, to calculate the number of refueling or
11 operating cycles remaining before the component reaches the minimum allowable wall
12 thickness."[35] This language is unequivocal and does not evince an understanding that the
13 usefulness of CHECWORKS in a FAC AMP is as a screening tool to establish component
14 inspection priorities.
15
16 In addition, industry guidance in EPRI's Recommendations for an Effective Flow-Accelerated
17 Corrosion Program, NSAC-202L, also do not indicate that the prime use of CHECWORKS is for
18 screening purposes and not for predicting absolute wear rates; quite the opposite, this guidance
19 states that "[t]he purpose of quantitative analysis [meaning using a predictive methodology such
20 as CHECWORKS] is to predict the FAC wear rate and to determine the remaining service life
21 for each piping component, including uninspected components."[36]
22
23 Moreover, even if this was an appropriate role for CHECWORKS at Indian Point, since
24 CHECWORKS does not provide accurate wear predictions, as discussed at length in my initial
25 testimony,[37] I do not believe CHECWORKS is a reliable screening tool to establish inspection

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[33] *GALL Report*, Rev. 1 at § XI.M17 ¶ 5 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[34] *GALL Report*, Rev. 1 at § XI.M17 ¶ 5 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[35] *GALL Report*, Rev. 1 at § XI.M17 ¶ 6 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 6 (NYS00147A-NYS00147D).
[36] EPRI, Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L-R3, at § 4.3 (RIV000012)..
[37] Hopenfeld Prefiled Direct at 5-10 (RIV000003).

priorities. For example, components that are assigned a low inspection priority may wear ten times faster than other components that are assigned as higher priorities. This notion is clearly supported by recently published data on the effects of chromium on FAC wear rates.[38]

Q. Entergy's witnesses disagree with your conclusion that CHECWORKS has very poor predictive accuracy, which you surmised because CHECWORKS provides highly non-conservative predictions 40%-60% of the time, and indicate that at Indian Point "CHECWORKS is logically expected to overpredict the wear rate 50% of the time and underpredict the wear rate 50% of the time."[39] Do you have a response to this testimony?

A. Entergy's witnesses' statements are completely contrary to the guidance contained in the *GALL Report*, Revision 2, that the use of CHECWORKS is acceptable because it provides a bounding, that is, conservative analysis, and that when measurements show the predictions to be non-conservative, the model *must be re-calibrated.*[40] Instead, Entergy's witnesses readily admit, and apparently agree with my assessment, that CHECWORKS produces non-conservative predictions about half of the time, however, they believe that such a circumstance is acceptable. This is inappropriate. Entergy's witnesses' testimony further indicates Entergy's apparent concession that recalibration of the CHECWORKS model is unattainable, since Entergy expects non-conservative predictions, 50% of the time, to continue. This is consistent with the reality that Entergy has been trying to recalibrate the code for the last 10 years with no apparent success.

Unlike Entergy's witnesses, I believe that there is a potential safety risk from such a large number of non-conservative predictions, evidenced by the fact that CHECWORKS can under predict the actual wall thickness by as much as a factor of 10. A predictive code that 50% of the time is not conservative by more than a factor of 1.5 (50%) and as high as a factor of 10 (900%), clearly poses a safety risk in connection with improper monitoring of component wall thinning.

Q. Entergy's witnesses also disagree with your conclusion that CHECWORKS has very poor predictive accuracy because they believe "there is adequate correlation and since

[38] Stéphane Trevin & Marie-Pierre Moutrille, *Optimization of EDF's NPPs Maintenance due to Flow Accelerated Corrosion and BRT-CICEROTM Improvement by NDT Results Analysis* (18th World Conference on Nondestructive Testing, 16-20 April 2012, Durban, South Africa) (Exhibit RIV000110).
[39] Entergy's Testimony at A102, A106, A109.
[40] *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).

"good correlation will not be achieved for all Analysis Lines"[41] Do you have a response to this testimony?

A. I disagree with Entergy's witnesses' characterization of CHECWORKS' predictions as generating "adequate correlation." As I discussed and demonstrated in my initial testimony at length, CHECWORKS over-predicts or under-predicts wall thinning by as much as a factor of 10.[42] In my professional opinion, such a wide margin, demonstrated by much of the data I reviewed, is not what I would consider "adequate correlation."

Q. Entergy's witnesses testify that your assessment that CHECWORKS produces highly inaccurate results does not indicate "a deficiency in the FAC program."[43] Do you agree with this conclusion?

A. No, I do not. While Entergy's witnesses do not challenge my conclusion that CHECWORKS produces inaccurate results in many instances (or the fact that this inaccuracy in many cases exceeds a factor of 2 and in some cases a factor of 10),[44] they do not characterize this as a deficiency. I emphatically disagree, and view the highly unreliable nature of the CHECWORKS model at Indian Point as problematic. Overall, my review revealed a data scatter on the order of 5-10, and the inability of the code to predict wear by as much as a factor of 10, which is significant from a safety perspective. This should preclude the use CHECWORKS as a tool for predicting wear.

In particular, in light of the gross inaccuracy of CHECWORKS for predicting wear of components at Indian Point, there is no confidence that CHECWORKS identifies the correct inspection locations, and, in turn, no confidence that Energy will develop an adequate inspection schedule. I previously provided examples showing that such inaccuracies could cause many components to operate with wall thicknesses below their design thickness.[45] This was not the intent of the *GALL Report*, which indicates that "[t]he inspection schedule developed by the licensee on the basis of the results of such a [properly benchmarked] predictive code" must

[41] Entergy's Testimony at A109.
[42] Hopenfeld Prefiled Direct at 5-10 (RIV000003); *see also* Report of Joram Hopenfeld in Support of RK-TC-2 ("Hopenfeld RK-TC-2 Report") at 4-18 (RIV000005).
[43] Entergy's Testimony at A114.
[44] *See* Hopenfeld Prefiled Direct at 6 (RIV000003); Hopenfeld RK-TC-2 Report at 7-8 (RIV000005).
[45] Hopenfeld Prefiled Direct at 10-11 (RIV000003); Hopenfeld RK-TC-2 Report at 13-15 (RIV000005).

"provide[] reasonable assurance that structural integrity will be maintained between inspections."[46]

While some variation in code predictions would be expected when compared to experiential data, since all measurements are subject to instrument errors and the chemical composition between components will always vary, a properly designed predictive tool would account for measurement uncertainties and variations in chemical composition. CHECWORKS, on the other hand, has inherent deficiencies in its design, and results in predictive variations that cannot be considered acceptable.

Moreover, the inability of CHECWORKS to predict FAC with any degree of accuracy is also a deficiency because it runs afoul of applicable guidance, including the *GALL Report* for the reasons discussed above. In addition, Entergy's FAC program document, EN-DC-315 requires that future inspections consider "CHECWORKS-predicted margins between nominal wall thickness and minimum required wall thickness."[47] However, because CHECWORKS predictions are highly inaccurate, Entergy cannot meet these criteria.

Q. Based on your assessment of Entergy's CHECWORKS data, in your initial prefiled testimony and accompanying report, you concluded that the CHECWORKS model is not currently benchmarked and, therefore, is an ineffective tool for detecting and managing FAC at Indian Point.[48] Entergy's witnesses disagree that the data and "selected" graphs you analyzed demonstrate a deficiency in CHECWORKS.[49] Do you have a response to this explanation?

A. My assessment of Entergy's CHECWORKS data involved reviewing *every* graph included in *every* CHECWORKS modeling report that was provided to me for review by Entergy. In total, I reviewed approximately 225 plots with 6,500 data points, memorializing my analysis in a table that was included in my expert report.[50] Thus, Entergy's characterization that

[46] *GALL Report*, Rev. 1 at § XI.M17 ¶ 5 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[47] Entergy's Testimony at A72.
[48] Hopenfeld Prefiled Direct at 5-10 (RIV000003); Hopenfeld RK-TC-2 Report at 4-13 (RIV000005).
[49] Entergy's Testimony at A104, A105, A106.
[50] Hopenfeld RK-TC-2 Report at 9-12 (RIV000005).

1 the graphs I excerpted from Entergy's reports and included in support of my testimony as
2 Exhibits RIV00016A and RIV00016B are "partial results" and "selected graphs" is misleading
3 and wrong. I did not simply point to "examples with poor agreement between wear predictions
4 and actual measurements,"[51] but rather included *all graphs from all reports*. There was nothing
5 selective about my analysis of Entergy's data, and I did not knowingly exclude any data.
6
7 In reality, all of this data, and not simply selected data, demonstrated the poor predictive
8 capability of CHECWORKS at Indian Point and the lack of correlation between predicted and
9 measured wear rates. All of the data I reviewed exhibited wide scatter, not simply "selected"
10 graphs and data. Moreover, I counted every data point that fell below the 45° line as a non-
11 conservative result, and every data point above the 45° line as a conservative result, to derive my
12 analysis as memorialized in Table 1 in my expert report.[52] My analysis clearly demonstrated that
13 about 50% of the time, CHECWORKS produced non-conservative predictions. Thus, my review
14 of Entergy's data led me to the correct conclusion that CHECWORKS at Indian Point cannot
15 predict wall thinning to any degree of accuracy. In fact, Entergy's own witnesses even testify
16 that "CHECWORKS is logically expected to overpredict the wear rate 50% of the time and
17 underpredict the wear rate 50% of the time."[53] This seems inconsistent with the witnesses' other
18 statements intimating that CHECWORKS produces accurate results too.
19
20 **Q. Entergy's witnesses testify to their belief that 0.5-2.5 is an acceptable range for a line**
21 **correction factor ("LCF") because of user experience and because this range was defined**
22 **by EPRI.[54] Do you agree with this assessment?**
23 A. As I explained in my prefiled direct testimony, I am not aware of any adequate
24 justification to support a conclusion that an LCF within the range of 0.5 to 2.5 is acceptable or
25 that an LCF within this range would be an indication that CHECWORKS can be used to
26 accurately predict inspection locations.[55] Entergy's witnesses' testimony has not changed my
27 opinion. In fact, Entergy's vague and general responses indicate to me that Entergy may not
28 know what the true reason for the LCF range is.

[51] Entergy's Testimony at A105.
[52] Hopenfeld RK-TC-2 Report at 9-12 (RIV000005).
[53] Entergy's Testimony at A109.
[54] *Id.* at A108.
[55] Hopenfeld Prefiled Direct at 7 (RIV000003).

Notably, Entergy's witnesses' perception that CHECWORKS is an "effective tool," does not constitute a technical justification for using the 0.5-2.5 criterion for either accepting or rejecting CHECWORKS' predictions. As the LCF constitutes a key criterion that dictates whether components should be reinspected or not, the criterion must be based strictly on safety considerations. The numerous Entergy documents I reviewed failed to provide any such technical explanation or justification. Not knowing the basis for the acceptance of this LCF range is an indication that Entergy does not know the safety risk of using CHECWORKS. My assessment of Entergy's data indicated that this acceptance criteria was exceed by as much as 17%,[56] yet Entergy does not appear to know the safety consequences of exceeding the EPRI criteria. Since the CHECWORKS data I reviewed represents a small fraction of all FAC susceptible components in the plant, one must conclude that a large number of components are operating outside the range of the EPRI criteria.

Moreover, Entergy's witnesses point to the fact that NRC Staff has endorsed the EPRI documents which "defined" the LCF range Entergy uses.[57] However, my review of various documents identified by Entergy and NRC Staff as relevant to Contention RK-TC-2 revealed no NRC documents providing a scientific basis for the 0.5-2.5 LCF inspection criteria range. Thus, simply because NRC Staff may blindly "endorse" the range, is not adequate justification for using it.

Q. Entergy's witnesses dispute your criticism of the fact that CHECWORKS fails to provide a single measured value for every predicted data point.[58] In particular, Entergy's witnesses attribute varying measured results to "different reasons, such as differing amounts of trace chromium in different components, uncertainties in component initial thickness, or uncertainties in NDE measurements."[59]

A. Entergy's witnesses' response as to why there is no one-to-one correspondence between predictions and measurements is inadequate. While some data scatter will always exist when

[56] Hopenfeld RK-TC-2 Report at 9-12 (RIV000005).
[57] Entergy's Testimony at A108.
[58] *Id.* at A110.
[59] *Id.*

1 code predictions are compared to experiential data, since all measurements are subject to
2 instrument errors and the chemical composition between components will always vary, a
3 properly designed predictive tool should account for such variations. CHECWORKS predictions
4 for example show that for one predicted value there were 17 thickness measurements ranging
5 from 30 to 250 mils–that is, variation by a factor of 8. In reality, the reason for the lack of
6 correlation is that CHECWORKS has inherent deficiencies in its design. State-of-the-art
7 computer codes, such as the one described in Stéphane Trevin & Marie-Pierre Moutrille,
8 *Optimization of EDF's NPPs Maintenance due to Flow Accelerated Corrosion and BRT-*
9 *CICEROTM Improvement by NDT Results Analysis*,[60] show an order of magnitude better
10 accuracy of predicting wall thicknesses, and relatively little scatter in comparison to
11 CHECWORKS.
12
13 **Q. Entergy's witnesses respond to your discussion of +/-50% lines located on graphs in**
14 **Entergy CHECWORKS reports plotting measured versus predicted wear.[61] In particular,**
15 **Entergy indicates that these lines "are there for the convenience of the reader of the report,**
16 **to provide consistent reference points across different graphs" and are not used by FAC**
17 **engineers to determine whether any CHECWORKS prediction is accurate or acceptable.[62]**
18 **Do you have a response to this explanation?**
19 A. I disagree that the +/-50% lines provide convenience to the reader. In fact, I believe that
20 the opposite is true, since these lines convey misleading information in two ways:
21
22 First, they incorrectly inform the reader about the degree of non-conservatism in CHECWORKS
23 predictions. Put another way, the -50% line masks the degree of deviation of non-conservative
24 predictions from actual measurements. As an example, I have excerpted one graph from a
25 CHECWORKS modeling report which shows a typical plot of CHECWORKS wear predictions
26 versus actual wall measurements at Indian Point Unit 2, redrawn it to focus on the non-
27 conservative portion of the plot (i.e. including only the data below the LCF line), and included

[60] Stéphane Trevin & Marie-Pierre Moutrille, *Optimization of EDF's NPPs Maintenance due to Flow Accelerated Corrosion and BRT-CICEROTM Improvement by NDT Results Analysis* (18th World Conference on Nondestructive Testing, 16-20 April 2012, Durban, South Africa) (Exhibit RIV000110).
[61] Entergy's Testimony at A111, A112.
[62] *Id.* at A111.

these in support of my rebuttal testimony.[63] In this redrawn plot,[64] it is clear that most of the non-conservative data, with the exception of five points, is bounded by the -50% line. Without counting actual points, the reader cannot tell the degree of non-conservatism. The picture becomes clearer when the measured wear is plotted on the y-axis and the predicted values are plotted on the x-axis, as seen in a second redrawn plot I have included in support of my testimony.[65] Now, one can easily see that fifteen data points, that is, three times as many, now fall above the 50% line.[66] So, by assigning the y-axis with predictions and the x-axis with measured wear, the non-conservative data appears to be bounded by the -50% line. When, however, that arrangement is reversed, many of data points, can be seen as under-predicting measurements by more than a factor of 1.5. In addition, the upper line (+50%) on some plots was displaced by a factor 2 instead a factor of 1.5, giving the impression that a much larger set of data points is being bounded. CHECWORKS performance graphs as presented are not showing the real truth, that is, that a large number of data points show underpredicted measurements by more than 1.5. A plot of CHECWORKS data with the y-axis as the measured wear and the x-axis as the predicted wear would have provided a much more informative and objective display of CHECWORKS performance. The manner in which CHECWORKS predictions are plotted by Entergy's vendor hides the fact that a very large number of data points fall outside a margin of 1.5 accuracy. In other words, the plots provided by Entergy mask the degree of non-conservatism of CHECWORKS predictions.

Second, the line in some of the plots misrepresents how much of the data is really bounded by the +50% line. I explained this in my initial testimony,[67] however, to reiterate and emphasize: in some plots, the line labeled 50%, actually represents a line of points which exceed the points on the 45° line by a factor of 2. To be consistent with the 50% label, the points on that line would have to be larger by a factor of only 1.5 but then that line would bound a smaller number of points. Thus, Entergy's presentation of the Indian Point CHECWORKS data exaggerates the bounding capabilities of the model.

[63] Hopenfeld, Demonstration of Flawed Presentation of CHECWORKS Data (RIV000111).
[64] *Id.* at Figure 2a.
[65] *Id.* at Figure 2b.
[66] *Id.*
[67] Hopenfeld Prefiled Direct at 6 (RIV000003); Hopenfeld RK-TC-2 Report at 6-12 (RIV000005).

The release of and reliance on misleading and incorrect information is an indication of a poor quality control of the FAC program at Indian Point.

Q. Entergy's witnesses further testify that you reference older, allegedly outdated, documents in support of your discussion of the +/-50% lines on CHECWORKS graphs, and that "more valuable information about the goodness-of-fit of the program's predictions" is available.[68] Do you have a response to this testimony?

A. For the reasons discussed above, I continue to believe that Entergy's use of +/-50% lines on CHECWORKS graphs is inappropriate, and misconstrues the data. The bottom line is that the wide scatter in and out of the +/-50% lines demonstrates a very wide margin of conservative and non-conservative predictions and complete lack of correlation. The relevant fact, which Entergy's witnesses confirm in their testimony, is that CHECWORKS at Indian Point underpredicts wear rates about 50% of the time. My review of thousands of data points indicates that the discrepancy between predictions and actual measurements varies as much as by a factor of 10. Thus, it is evident that CHECWORKS is "unfit," notwithstanding my discussion of older documents.

Q. Entergy's witnesses dispute your characterization of the highly erratic nature of CHECWORKS predictions by indicating that certain analysis lines are not calibrated.[69] Do you have a response to this explanation?

A. I assumed that the data Entergy provided was complete and ready for evaluation and assessment. Notably, the CHECWORKS reports containing the graphs I reviewed did not specify which graphs were calibrated and which were not. If some data was not ready for evaluation, Energy should have not released that data, or provided an explanation in order to fully understand the graphs.

My review of the data provided showed erratic and inaccurate predictions for a large majority of the data. For example, one plot contained in an Entergy's CHECWORKS report[70] is one

[68] Entergy's Testimony at A112.
[69] *Id.* at A114.
[70] *See* RIV00016A at CSI Technologies, Inc., Indian Point Unit 2 CHECWORKS SFA Model, CSI Calculation No. 0705.101-01, Revision A, November 17, 2008, pageJ-5 of 36 (plot J.4: 4th Point Extrac Stm).

example of erratic predictions and/or unexplained behavior, as well as the lack of proper quality controls in Entergy's FAC program. This plot shows no wall thinning predictions and the measurements show thinning vary from 25 to 180 mils.[71] It is, needless to say, difficult to completely evaluate this kind of information in the absence of sufficient explanations from Entergy.

Q. Entergy's witnesses testify that "CHECWORKS is universally accepted in the United States as the best available analytical tool for prioritizing inspections for a FAC program . . . and has been endorsed by the NRC Staff."[72] What is your response to these statements?

A. I do not believe that CHECWORKS is the best analytical tool for *predicting* wall thinning, which is how the *GALL Report* contemplates its use. In particular, NRC's guidance in the *GALL Report*, indicates NRC's belief that "CHECWORKS is acceptable because it provides a bounding analysis for FAC. The analysis is bounding because in general the predicted wear rates and component thicknesses are conservative when compared to actual field measurements."[73] In addition, I also do not agree that CHECWORKS is the best analytical tool for prioritizing inspection locations. Entergy's witnesses' statement is self-serving. EPRI aggressively markets this tool.

Although I am not aware of the reasons why, the reality is that NRC endorses the use of CHECWORKS. It is naïve to believe that once the NRC specifically endorses a single and a specific computer code, any plant operator in the US would not use it. However, there is no evidence that CHECWORKS was peer reviewed by an independent group of experts, and NRC Staff has provided no scientific justification for using CHECWORKS as a predictive tool at Indian Point.

[71] *See id.*
[72] Entergy's Testimony at A114.
[73] *GALL Report*, Rev. 1 at § XI.M17 ¶ 5 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).

Lastly, Entergy's witnesses' confidence in CHECWORKS begs the question: if CHECWORKS is so reliable, why is it that its contribution is limited only to 25% of Entergy's total FAC program?

Q. Entergy's witnesses testify that Entergy has updated the CHECWORKS model to account for the stretch power uprates ("SPUs") that occurred at Indian Point Units 2 and 3 in 2004 and 2005, respectively, and that "the overall accuracy of the CHECWORKS model was not significantly affected by the SPUs."[74] Do you agree with this assessment?

A. I agree that the grossly inaccurate predictions produced from CHECWORKS before the SPUs continued after the SPUs. I discussed this at length in my initial testimony and expert report, and further below.[75]

Q. Entergy's witnesses testify that CHECWORKS does not monitor or generate data in relation to components inside the steam generators at Indian Point.[76] Do you have a response to this explanation?

A. Components inside the steam generators, as well as valves and blow down lines, are important safety/risk-significant components that are highly vulnerable to FAC and fall within the license renewal rule, and yet are not monitored at all by CHECWORKS. For example, the steam generator feedring is subjected to very high turbulence especially at the flow stagnation area, yet is not monitored by CHECWORKS to determine inspection intervals. In my professional opinion, this is problematic, and fails to ensure that the steam generator will maintain its integrity, in particular, during design basis accidents such as main steam-line breaks and station blackouts. It remains unclear how such components are screened. Notably, EPRI's guidance does not recommend the use of tools other than a quantitative predictive model such as CHECWORKS.[77] Furthermore, the *GALL Report* encompasses all FAC-susceptible components.

Q. Entergy's witnesses disagree with your position that CHECWORKS does not

[74] Entergy's Testimony at A91, A92.
[75] Hopenfeld Prefiled Direct at 5-10 (RIV000003); Hopenfeld RK-TC-2 Report at 5-13 (RIV000005).
[76] Entergy's Testimony at A64.
[77] EPRI, Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L-R3 (RIV000012).

ensure that all forms of FAC will be adequately managed.[78] Do you have a response to this testimony?

A. To begin with, I continue to respectfully disagree with Entergy's arbitrarily restrictive definition of FAC, which improperly excludes wall thinning by cavitation, wet steam, galvanic corrosion, and jet impingement/erosion even though all are effected by flow velocities.[79] Based upon Entergy's characterization of a statement I made during the *Vermont Yankee* nuclear power plant license renewal proceeding, it appears that Entergy lacks understanding of certain basic principles of FAC, as well as the underlying assumptions in CHECWORKS, as I discussed earlier.[80] Moreover, Entergy leaves out wall thinning by all mechanisms other than chemical dissolution. Notably, the theory espoused by EPRI that FAC is strictly controlled by metal dissolution is not universally accepted. Other researchers believe that fluid shear forces are sufficiently large to remove the protective oxide film and thereby control wall thinning.

This is a limitation on Energy's use of the CHECWORKS computer code at Indian Point, since the CHECWORKS model does not predict wall thinning by these other mechanisms, including cavitation or droplet impingement. Entergy's witnesses appear to believe that just because EPRI defined FAC as a process controlled by chemical dissolution only, wall thinning by cavitation and wet steam do not require a predictive methodology. This is not accurate. Notably, a model which combines mechanical and chemical mechanisms would predict much higher velocity dependence than CHECWORKS predicts. Very high dependence of wall thinning on velocity has been observed in laboratories.

However, Entergy's witnesses indicate that "inspection locations for erosive mechanisms are selected based on operating experience by other IPEC programs (e.g., thermal performance has identified a leaking valve), and engineering judgment."[81] Entergy's witnesses' vague and general description makes it impossible for me to assess whether Entergy is adequately managing these other mechanisms, or whether Entergy will be able to adequately manage such mechanisms during the proposed periods of extended operation. It appears that at least in some

[78] Entergy's Testimony at A51 (discussing Hopenfeld Report at 2 (RIV000005)); *see also id.* at A101.
[79] *Id.* at A51.
[80] *Supra* pp. 7-8.
[81] Entergy's Testimony at A101.

cases the programs relies on pinhole leaks for future inspection. Pinhole leaks, through sentry holes, were commonly used in refineries prior to 1950 to locate areas with excessive wall thinning.

V. The CHECWORKS Model is Not, and Will Not Become, Adequately Benchmarked at Indian Point

Q. Entergy's witnesses testify that "there is no need for extended post-SPU calibration or benchmarking over a period of multiple years or outage cycles *before* CHECWORKS can be used as part of the FAC Program."[82] Do you have a response to this assertion?

A. For the reasons discussed at length in my initial testimony, I disagree with Entergy's witnesses' statement, and continue to offer my expert opinion that because the model at Indian Point clearly lacks adequate benchmarking, and cannot be used as part of the FAC program. Based on my review of Entergy's witnesses' testimony, as well as a recently published study on new data and a different computer code,[83] I believe that the design of CHECWORKS is so fundamentally flawed that recalibration efforts will not be successful.

In particular, Entergy's CHECWORKS data reveals a constant lack of correlation over a period of numerous years, and the data further reveals no signs that CHECWORKS' predictions are improving with time, it appears unlikely that the model could be sufficiently recalibrated in the future, and certainly not before Indian Point would enter the imminent extended operating terms Entergy is seeking.[84] In fact, this notion is confirmed by Entergy's witnesses, who testify that CHECWORKS was designed to "overpredict the wear rate 50% of the time and underpredict the wear rate 50% of the time."[85] This reveals Entergy's witnesses' understanding that the CHECWORKS model will not be properly calibrated in the future, and therefore, Entergy's use of CHECWORKS is not consistent with Revision 2 of the *GALL Report*.

[82] Entergy's Testimony at A115 (emphasis in original); *see also id.* at A116.
[83] Stéphane Trevin & Marie-Pierre Moutrille, *Optimization of EDF's NPPs Maintenance due to Flow Accelerated Corrosion and BRT-CICEROTM Improvement by NDT Results Analysis* (18th World Conference on Nondestructive Testing, 16-20 April 2012, Durban, South Africa) (Exhibit RIV000110).
[84] Hopenfeld Prefiled Direct at 5-10 (RIV000003); Hopenfeld RK-TC-2 Report at 4-13 (RIV000005).
[85] Entergy's Testimony at A109.

In addition, Entergy's witnesses have attributed the inaccuracy of CHECWORKS predictions to chromium content in the components and measurement uncertainties. Recent data shows that the uncertainty in chromium alone could affect FAC wear by an order of magnitude. Thus, Entergy's witnesses identification of the presence of chromium is further evidence that extended recalibration of the code is necessary, even if more accurate methods were used to determine component chromium content.

It remains my opinion that because the CHECWORKS code is not adequately benchmarked, despite years of continuous recalibration, it cannot be used reliably to schedule inspection intervals, screen components for inspection, or to ensure that the structural integrity of components between inspections will be maintained.

Q. Entergy's witnesses believe that extended post-SPU benchmarking of CHECWORKS at Indian Point is not necessary because "one of the goals of developing CHECWORKS was to allow the user to predict the impact of changes of input parameters."[86] Do you have a response to this statement?

A. The fact that the code user can perform the mechanical task of changing or tweaking input parameters is not a sign that the code has been recalibrated. There is only one way of demonstrating that the code has been recalibrated, and therefore consistent with the guidance contained in the *GALL Report*: comparing CHECWORKS predictions against actual measured component thickness measurements. As my analysis, as contained in Table 1 of my expert report, shows, the predictions of the recalibrated code (that is those predictions made after the SPUs), are not different than the earlier results.[87] In all cases, approximately 50% of the data points are non-conservative, most of the time by a factor of two (that is, by 100%), but also upwards of in excess of a factor of 10 (that is, by 1000%).[88]

Q. Entergy's witnesses testify that extended post-SPU benchmarking of CHECWORKS at Indian Point is not necessary because "CHECWORKS was designed, and has been shown, to accommodate changes in chemistry, flow rate and other operating

[86] Entergy's Testimony at A115.
[87] Hopenfeld RK-TC-2 Report at 9-12 (RIV000005).
[88] *Id.*

conditions that may be associated with power uprates, without inspection data from multiple outages."[89] Do you have a response to this statement?

A. My analysis of Entergy's CHECWORKS data, as memorialized in Table 1 of my expert report, does not support this claim. In particular, my analysis clearly demonstrates that following each post-SPU refueling outage at Indian Point, the code has remained uncalibrated and therefore not consistent with the *GALL Report*. The data shows no improvement in CHECWORKS predictions; it consistently produces non-conservative predictions by a wide margin. I, therefore, disagree that the CHECWORKS code at Indian Point has adequately accommodated the changes in plant operating parameters following the SPUs.

Entergy's witnesses support their statement by citing to an EPRI study where EPRI concluded that CHECWORKS' predictions in 22 reactors, notably *not* including Indian Point, were reasonable following power uprates. The same document also states that the CHECWORKS analysis is plant specific.[90] At Indian Point, the outcome of CHECWORKS' predictions do not agree with EPRI's observations.

Q. Entergy's witnesses cite to an Entergy response to a "request for additional information" ("RAI") in which Entergy stated that "[d]ue to the low wear rates, the small changes in operating parameters due to SPU, and the relatively short time since SPU, changes to wear rates since SPU will be very small. The accuracy of the model is not expected to change significantly due to the SPU" and that "additional data sets [following SPU] when added to the CHECWORKS database, will result in more refined wear rate predictions."[91] Entergy's witnesses then testify that they agree with Entergy's conclusion in the RAI response, and believe that "the validity of the IPEC CHECWORKS model did not change significantly due to the SPU."[92] Do you have a response to this testimony?

A. To begin with, Entergy's response to NRC Staff's RAI is misleading, because it hides the fact that CHECWORKS predictions at Indian Point are non-conservative 50% of the time, with many of the actual measurements higher than predictions by a factor of two and as much as a

[89] Entergy's Testimony at A116.
[90] EPRI, Plant Engineering: Impact of Electric Power Uprates on Flow-Accelerated Corrosion (July 2011) ENT000081 at p.1-3.
[91] Entergy's Testimony at A117.
[92] *Id.* at A118.

factor of 10. Nor does Entergy's RAI response indicate that wear to steam generator components were not included in the CHECWORKS database.

Overall, for the reasons stated in this rebuttal testimony, as well as in my initial testimony, I disagree that additional post-SPU data sets adequately "refined" the CHECWORKS model, though do agree that the accuracy of the CHECWORKS model has not changed significantly: as evidenced by more than 6,500 data points I analyzed, the model produced grossly inaccurate predictions before the SPUs, and this continued after the SPUs. The scatter of the predictions is so wide that no comparison is possible for any period since approximately 2000 (that is, the years for which Entergy provided data).

Q. Entergy's witnesses testify that NRC Staff concluded in its SER that "CHECWORKS is 'a self-benchmarking' computer code."[93] Do you agree with this characterization?

A. No, I do not. Notably, the relevant issue is not whether CHECWORKS is manually or automatically adjusted to accommodate changes in plant parameters, but rather, whether the predictions of the recalibrated code are accurate and actually demonstrate that the code has been sufficiently benchmarked, as required by the *GALL Report*. As discussed at length above and in my initial testimony, this is not the case at Indian Point, and this is not likely to be demonstrated prior to, or during, Entergy's proposed periods of extended operations.

Q. You indicated earlier that you reviewed additional CHECWORKS reports which Entergy disclosed and provided *after* your initial testimony was submitted in this proceeding. Can you describe these reports?

A. At the end of March, 2012, Entergy disclosed approximately 20 additional, previously-undisclosed CHECWORKS modeling reports relating to Indian Point Unit 3. The dates of these reports varied from 1999 to 2004 and discussed CHECWORKS data from several different refueling outage FAC inspections at Unit 3. I am aware that in the context of a document dispute between the parties that occurred around August of 2010, Entergy had indicated that CHECWORKS data relating to Unit 2 prior to 2000 could not be located, but that Entergy had

[93] Entergy's Testimony at A119.

committed to disclose all available documentation related to CHECWORKS for Unit 3 dating back to 2001. Thus, Entergy's March 2012 disclosure of these additional documents included several which should have been disclosed earlier in accordance with Entergy's commitment to do so, but also several other additional earlier reports.

While it is my understanding that in resolving the parties' document dispute the ASLB ruled that Entergy did not have to disclose historical CHECWORKS data, I am aware that CHECWORKS has been used at Indian Point since it was developed in or around the late 1980s/early 1990s. Thus, the newly disclosed documents still do not constitute all of the CHECWORKS data that has been generated from using the model at Indian Point.

Q. Do you have any conclusions based upon your review of the additional CHECWORKS modeling reports disclosed by Entergy in March 2012?

A. I reviewed the data plots contained in these reports of CHECWORKS wear predictions of component wall thickness relative to actual measurements. Once again, I have excerpted these plots and included them in support of my rebuttal testimony.[94] My review of this additional data confirms and supports my previous testimony and opinion that the CHECWORKS computer code produces highly unreliable and non-conservative component wear predictions. Like the previous plots I analyzed, these plots likewise exhibit wide scatter, and a high percentage of non-conservative results. This data supports my conclusion that even prior to the SPUs at Indian Point, the CHECWORKS code lacked adequate benchmarking, that the calibration of the code has not improved with time, and that the code has never been properly benchmarked.[95]

Based on my review of this additional CHECWORKS data, I continue to offer my professional expert opinion that CHECWORKS is an ineffective tool for selecting and prioritizing piping and piping component locations at Indian Point for inspections and wall thickness measurements, and that the model will not be properly calibrated before Indian Point enters the rapidly approaching proposed PEO.

[94] Graphs from CHECWORKS Reports (Excerpts) (RIV000112).
[95] Hopenfeld Prefiled Direct at 5-7 (RIV000003); Hopenfeld RK-TC-2 Report at 4-13 (RIV000005).

VI. Entergy's Witnesses Inapposite Discussion of and Reliance on Findings Made in Vermont Yankee Proceeding

Q. Entergy's witnesses testify at various points about findings made by a different ASLB about FAC and CHECWORKS in the *Vermont Yankee* license renewal proceeding.[96] Do you have an overall response to such testimony?

A. It is my understanding that a licensee must demonstrate that it has an adequate AMP for FAC *at Indian Point*, which makes findings that relate specifically to Entergy's program at the Vermont Yankee plant irrelevant.

In particular relation to the benchmarking of CHECWORKS, a discussion of what happened in a different license renewal proceeding is irrelevant, because a CHECWORKS analysis is plant-specific.[97] For example, EPRI has explained that "[a]s plant configurations, amounts of resistant material and way in which the uprate is performed vary greatly, the CHECWORKS™ analysis is plant specific."[98] Moreover, the Vermont Yankee adjudicatory hearings were held before the *GALL Report*, Revision 2 was issued, which specifically requires recalibration of the CHECWORKS code if it produces non-conservative results. Thus, Entergy's witnesses' reliance on a proceeding that occurred when there was a different understanding of applicable guidance is clearly inappropriate.

In general, notwithstanding Entergy's witnesses' testimony, I continue to opine that there are several critical differences between the Vermont Yankee and Indian Point plants that also makes the ASLB's findings in the former proceeding unreliable, including the size and type of reactors at issue.

Q. Entergy's witnesses cite the ASLB in the *Vermont Yankee* license renewal proceeding as stating that the intervenors' experts in that case "may be misunderstanding

[96] *See* Entergy's Testimony at A53, A115, A116, A121, A123-A130.
[97] Hopenfeld Prefiled Direct at 9 (RIV000003).
[98] EPRI, Plant Engineering: Impact of Electric Power Uprates on Flow-Accelerated Corrosion (July 2011) ENT000081 at p.1-3.

the purpose of CHECWORKS in the FAC program in their attempt to use continuous benchmarking of the model to predict absolute wear."[99] Do you have a response to this?

A. While I completely understand Entergy's stated purpose for which it uses CHECWORKS at Indian Point, that is, as simply a ranking tool, I disagree with the appropriateness of doing this. My understanding of the purpose of CHECWORKS is based on applicable regulations and guidance, which, as I've discussed already, contemplate CHECWORKS as a quantitative predictive tool, and which require recalibration of the model when results are non-conservative.[100]

Notably, in the *Vermont Yankee* proceeding, which I recall participating in, the emphasis remained on Entergy's use of the CHECWORKS code was for *predictive* purposes, and not relative comparison purposes. It is, therefore, difficult to understand Entergy's dependence upon findings made in the Vermont proceeding when it uses the code in such a different manner at Indian Point.

Q. Entergy's witnesses dispute your testimony distinguishing the findings in the *Vermont Yankee* proceeding due to the small size of the Vermont Yankee plant.[101] Do you have a response to this?

A. I continue to believe this is a valid difference that renders the findings made in the *Vermont Yankee* proceeding unique to the Vermont plant, and not necessarily applicable to the Indian Point proceeding. In addition, this testimony is somewhat puzzling to me, since, during the *Vermont Yankee* proceeding, one of Entergy's witnesses specifically testified that the effect of the size of the plant effects FAC:

> Q22 Are there features of the VY design that result in a reduction of the amount of piping and components at a typical plant that are potentially susceptible to FAC?
> A22 (JCF) Yes. Compared to the majority of nuclear power plants in operation, VY is a relatively small and simple plant. There are fewer FAC-susceptible systems and piping components than at a typical plant, and many of those were either originally constructed

[99] Entergy's Testimony at A115 (citing *Entergy Nuclear Vt. Yankee* (Vt. Yankee Nuclear Power Station), LBP-08-25, 68 NRC 763, at 891 (2008).
[100] *See GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[101] Entergy's Testimony at A126.

> of FAC-resistant materials or have been replaced with FAC-resistant materials since their initial installation.[102]

Dr. Horowitz testifies inconsistently in this proceeding that the size of Indian Point will not affect FAC wear because velocities are about the same. I agree with Entergy's witness' own opinion that the size of a plant will affect FAC, I continue to opine that this distinguishes any findings made in the *Vermont* proceeding from the instant case.

Q. Entergy's witnesses dispute your testimony that the findings of the ASLB in the *Vermont Yankee* proceeding were inapposite because in that case post-SPU data was not available.[103] Do you have a response?

A. I continue to believe that this is a critical difference that makes the ALSB findings in the *Vermont Yankee* proceeding totally inappropriate to apply in this proceeding related to Indian Point. As I discussed in my initial testimony, the actual data from more than three post-SPUs show that CHECWORKS produces non-conservative results more than 50% of the time, and is, thus, not adequately calibrated. In contrast, there was no post-power uprate data in the *Vermont Yankee* proceeding. Thus, the finding in the *Vermont Yankee* proceeding that CHECWORKS did not require extended benchmarking following a SPU, clearly does not apply to a case where concrete data supports a contrary conclusion: a look at almost any one of the hundreds of plots of CHECWORKS predictions shows beyond a doubt that CHECWORKS produces a high percentage of (at times grossly) non-conservative results, and thus, as required by the *GALL Report*, must be recalibrated. A finding that was made without the benefit of actual data, essentially in a vacuum, and before the clarification in the *GALL Report* about the necessity of recalibrating the CHECWORKS model when it produces non-conservative results, is simply irrelevant to this case.

Q. Entergy's witnesses dispute your testimony that the findings of the ASLB in the *Vermont Yankee* proceeding were inapposite because in that case the board found prolonged benchmarking unnecessary since Vermont Yankee had the benefit of data

[102] In the Matter of Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. (Vermont Yankee Nuclear Power Station), Docket No. 50-271 –LR, ASLBP No. 06-849-03-LR, Testimony of Jeffrey S. Horowitz and James C. Fitzpatrick on NEC Contention 4 – Flow-Accelerated Corrosion (May 12, 2008), at 12-13(RIV000113).
[103] Entergy's Testimony at A128.

dating back to 1989, whereas at Indian Point, data predating approximately the year 2000 had been lost.[104] In particular, Entergy's witnesses testify that even though data dating back to the inception of the FAC program at Indian Point was not available and/or disclosed, the data has been incorporated into and reflected in the CHECWORKS model.[105] Do you have a response to this explanation?

A. To begin with, it was my understanding (based on representations made by Entergy, which were confirmed by the ASLB in a ruling on a document disclosure dispute about CHECWORKS data), that older, historical CHECWORKS data related to Indian Point was unavailable, and/or too burdensome to disclose. Notably, although Entergy provided certain additional CHECWORKS reports recently in March, 2012, as I discussed above, these reports dated back only to 1999, and still did not cover the time period dating back to the original use of CHECWORKS at Indian Point.

I find Entergy's witnesses' reference to the incorporation of historical CHECWORKS data into the model problematic to the extent Entergy's witnesses and Entergy rely upon this older data, (and the fact that it has been incorporated into the CHECWORKS model), to demonstrate that the code has been properly benchmarked and does not require "prolonged benchmarking." In order to assess such claims, it would be necessary for me to actually review the data; I could not simply rely on the fact that such data has allegedly been incorporated into the model. This is consistent with the ASLB ruling that because Entergy did "not have ready access to the data requested" they "cannot, rely on it to provide the track record for its AMP that Riverkeeper claims is lacking" or to "demonstrate that its use of CHECWORKS is adequately benchmarked."[106] And yet, despite the fact that no older data was required to be disclosed based on Entergy's representations in this case and the fact that I have, therefore, not reviewed any historical data, Entergy now appears to want to rely on it to support its reliance on CHECWORKS. In my opinion, Entergy cannot point to older data in this way.

[104] Entergy's Testimony at A129.
[105] *Id.*
[106] In the Matter of Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), Docket Nos. 50-0247-LR and 50-286-LR, ASLBP No. 07-858-03-LR-BD01, Order (Ruling on Riverkeeper's Motion to Compel) (November 4, 2010), at 5.

In any event, the CHECWORKS data that *was* disclosed overwhelmingly shows the fact that the code has consistently provided highly non-conservative predictive results, and that over the time span of the data I reviewed (from approximately 1999 to 2011), the code has not improved. Based on the behavior of the code that I was able to analyze based upon data, I do not believe that the additional historical data, which I have not had the benefit of reviewing, would materially change my opinions and conclusions. Based on how the model has behaved (that is, consistently poorly) since 1999, I believe that the historical data would actually in all likelihood bolster and be consistent with my findings.

VII. Leaks at Indian Point Demonstrate a Defective FAC Program

Q. Entergy's witnesses dispute your discussion of various leaks and wall thinning events at Indian Point, which you testified are indicative of a deficiency in the FAC program at Indian Point.[107] Do you have a response to this testimony?

A. It is puzzling to me that when leaks or excessive instances of wall thinning occur, Entergy can claim such instances are "program successes," and that, despite these events, the FAC program nevertheless performs well.

Although Entergy's witnesses explain that various leaks I discussed did not occur under the FAC program, the *GALL Report* requires that all FAC-susceptible components be properly monitored, whether they fit Entergy's definition of FAC or not. In many instances it is difficult to establish the exact mechanism that caused wall thinning. Moreover, the main purpose of a well-executed program is to prevent failures by wall thinning regardless of whether it is managed by the FAC program as defined by Entergy.

In addition, I strongly dispute Entergy's witnesses' explanation that certain leaks do not demonstrate a FAC program deficiency because the leak was of "negligible safety significance."[108] I disagree that such leaks are not a cause for concern. Small leaks, if not controlled in a timely manner, can grow in size or damage adjacent equipment and quickly become a safety risk. For example, the occurrence of a large rupture in a non-safety area at the

[107] Entergy's Testimony at A131 to A134.
[108] *Id.* at A132.

Surry plant quickly propagated to safety areas. At Surry, 20% of the wall thickness was lost in less than 18 months. This was sufficient to cause a major rupture when the line pressure was suddenly increased by 20% due to a valve closure. Although the rupture occurred in a non-safety area, it resulted in seepage of toxic chemicals into the control room. Thus, the witnesses' trivialization of small leaks is superficial.

Simply because Entergy instituted corrective action in response to the leak and thinning events I cited to, does not mean that such events are acceptable and consistent with applicable guidance, which requires adequate management of FAC. I, therefore, continue to opine that the operational events I testified about in my initial testimony do demonstrate a deficiency in Entergy's FAC program.

VIII. The Relevance of FAC Occurrences and the Failure of CHECWORKS at Other Nuclear Power Plants

Q. Entergy's witnesses dispute your discussion of FAC instances that have occurred at other nuclear plants and the failure of CHECWORKS on a global scale.[109] Do you have a response to this testimony?

A. I disagree with Entergy's witnesses' testimony about the relevance and implications of the various events of FAC and use of CHECWORKS at other nuclear plants, which I discussed in my initial testimony and expert report.[110] Entergy's witnesses' testimony does not change my opinions regarding the significance of these events, or the unreliability of CHECWORKS.

For example, Dr. Horowitz testifies that a FAC event that occurred at San Onofre that I raised in my initial hearing submissions, did not indicate a problem with the use of CHECWORKS or Entergy's FAC program because "[a]t San Onofre, the cited events occurred within the plant's steam generators" and "CHECWORKS was not used to analyze these components (and, even today, it is not commonly used to analyze piping components located within equipment such as steam generators)."[111] However, the fact that CHECWORKS was not used to predict many

[109] Entergy's Testimony at A135 to A140.
[110] Hopenfeld RK-TC-2 Report at 15-18 (RIV000005); Hopenfeld Prefiled Direct at 11-12 (RIV000003).
[111] Entergy's Testimony at A.135.

components in steam generators is not a valid explanation of why many of FAC wall thinning events have gone undetected. In addition, I continue to maintain, as I discussed above, that all FAC-susceptible components must be monitored, as dictated by the guidance in the *GALL Report*, whether CHECWORKS is used or not. Thus, this example does raise a valid deficiency with Entergy's reliance on CHECWORKS, and, Entergy's FAC program overall.

By way of another example, Dr. Horowitz also disputed my conclusion that CHECWORKS was not adequate to model the flow situation that was present at the Mihama plant. Dr. Horowitz testified that "some of the single-phase data from the UK [United Kingdom] showed the FAC rate downstream of an orifice, such as Mihama. These data were used extensively in developing the algorithm used in CHECWORKS" and concluded that "CHECWORKS is capable of correctly modeling the flow conditions that existed at Mihama."[112] However, turbulence intensity and, therefore, the local corrosion/erosion rate down stream of an orifice is a well known observation. It is true that CHECWORKS allows the user to take such information into account, but in some cases the data is questionable, such as measurements of corrosion rates of copper in flowing hydrofluoric acid. The dependence of the mass transfer on velocity as it was modeled in CHECWORKS is also questionable. Therefore, Dr. Horowitz's explanation does not change my opinion about the inability of CHECWORKS to adequately account for and model all relevant flow situations.

IX. Entergy's Failure to Comply with Relevant Regulatory Guidance

Q. Entergy's witnesses testify that "the IPEC FAC Program is consistent with the recommendations in NUREG-1801, Revision 1 [the *GALL Report*]" and "also meets the intent of the guidance in NUREG-1801, Revision 2."[113] Do you have a response to this position?

[112] Entergy's Testimony at A136.
[113] *Id.* at A141.

A. I disagree with this position. For the reasons discussed at length in my initial testimony and expert report,[114] and in this rebuttal testimony, Entergy's AMP for FAC does not meet the guidance contained in the *GALL Report*.

To begin with, Entergy's witnesses' testimony fails to acknowledge a critical difference between Revisions 1 and 2 of the *GALL Report*, in that the latter and most recent revision requires the recalibration of the CHECWORKS code when the results are non-conservative.[115] In fact, both revisions of the *GALL Report* indicate that the use of the CHECWORKS code is acceptable because it provides a bounding, conservative analysis.[116] However, as discussed above, Entergy's FAC program does not heed this guidance, and Entergy's witnesses instead indicate their position that the code at Indian Point is *expected to and does* produce non-conservative results about 50% of the time.[117] Indeed, my extensive review of the performance of CHECWORKS at Indian Point clearly demonstrates a continuous trend of highly non-conservative, inaccurate results, as discussed at length in my expert report and initial testimony.[118] In this glaring respect, Entergy's FAC program does not meet the guidance of the *GALL Report*. In fact, it is difficult to understand how, in light of the overwhelming evidence about the non-conservative nature of CHECWORKS predictions at Indian Point, which Entergy's witnesses testify to, Entergy can still claim compliance and consistency with the *GALL Report*.

Moreover, as discussed in my initial testimony, and in my discussion above of Entergy's alleged "other tools" for managing FAC, it remains my professional opinion that Entergy has yet to provide sufficiently detailed information to ensure its program is otherwise consistent with the *GALL Report* and other relevant standards. It is not sufficient for Entergy to just state that it adopted the elements outlined in the *GALL Report*. Entergy must describe how those elements will be implemented to ensure that the critical wall thickness of all susceptible components will be maintained between inspections. Entergy has not done this. Thus, Entergy's witnesses have

[114] *See* Hopenfeld Prefiled Direct at 16-18 (RIV000003); Hopenfeld RK-TC-2 Report at 18-19, 25 (RIV000005).
[115] *See* Entergy's Testimony at A48; *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[116] *GALL Report*, Rev. 1 at § XI.M17 ¶ 5 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).
[117] Entergy's Testimony at A102, A106, A109.
[118] *See* Hopenfeld Prefiled Direct at 5-10 (RIV000003); Hopenfeld Report at 4-13 (RIV000005).

not demonstrated that the effects of aging for FAC-susceptible components will be adequately managed as outlined by 10 elements in the *GALL Report*.

Q. Entergy's witnesses testify that NRC Staff concluded in its SER that the FAC program at Indian Point was acceptable and consistent with the ten program elements contained in the *GALL Report*.[119] Do you have a response to this?

A. It appears that NRC Staff's conclusions in the SER were based on materially different information about Entergy's FAC program than has been presented in Entergy's testimony. In particular, Entergy's testimony has revealed for the first time how relegated Entergy's use of CHECWORKS is, and how Entergy largely relies upon "other tools." This was not clear by Entergy's statements in its LRA that Entergy's FAC program was based on the *GALL Report* and NSAC-202L, both of which focus on the use of a quantitative predictive code. NRC Staff's discussion of Entergy's FAC program in its SER, as well as the testimony NRC Staff provided on Contention RK-TC-2, indicate NRC Staff's apparent understanding of CHECWORKS as the main tool to predict component wall thickness for scheduling inspection intervals at Indian Point.[120] Thus, it does not appear appropriate for Entergy to rely on conclusions made in the NRC Staff's SER.

X. The Failure of Entergy's FAC Program to Address Critical Safety Issues

Q. Entergy's witnesses disagree with your position that FAC at Indian Point poses an accident risk at Indian Point, and state that this position "presupposes a deficiency in the FAC Program, which is not the case."[121] Do you have a response to this testimony?

A. As I discussed in my initial testimony and expert report, as well as in this rebuttal testimony, Entergy's FAC program contains numerous deficiencies, making the risk of an accident very real.[122] My observations that Entergy is not using CHECWORKS to detect FAC in the steam generators and for other risk significant components, and that Entergy has not sufficiently described how the "other tools" in the FAC program at Indian Point are used (such as

[119] Entergy's Testimony at A58.
[120] SER at pp. 3-21 to 3-31.
[121] Entergy's Testimony at A142.
[122] Hopenfeld Prefiled Direct at 10-11, 18-20 (RIV000003); Hopenfeld RK-TC-2 Report at 24-25 (RIV000005).

failing to provide information about uncertainties in selecting measurement points, frequency of inspection, measurements accuracy, and safety consequences), lead me to the fully supported conclusion that FAC may go undetected in some components during the extended period of operations, posing an accident risk.

I continue to opine that after forty years of operation, some critical components may be operating with wall thicknesses below the minimum allowable, unknown to Entergy, and, therefore, would be vulnerable to failure when exposed to loads from design basis accidents, including Main Steam Line Breaks. Entergy's witnesses ignore this foreseeable circumstance. Notably, the Indian Point current licensing basis ("CLB") requires that that the plant be able to accommodate such accidents.

Q. Entergy's witnesses disagree with you position that Entergy has failed to adequately consider how the uncertainty related to pipe wall thickness at Indian Point will affect component integrity under transient loads, including earthquakes and station blackouts. In particular, Entergy's witnesses testify that "[w]hen FAC Program inspections reveal wall thinning, that data is evaluated against the appropriate design loading conditions, including seismic loads."[123] Do you have a response to this testimony?

A. To begin with, for the reasons discussed in my initial testimony and expert report, as well as in this rebuttal testimony,[124] I disagree that Entergy's FAC program "provides reasonable assurance that components within its scope will continue to perform their intended functions throughout the PEO."[125] Entergy's witnesses' testimony about this issue presupposes that the FAC program will not miss detection of excessive wall thinning. This, of course, is a highly unrealistic assumption given forty years of operating experience showing otherwise. As discussed above, my observations about the various deficiencies in Entergy's FAC program make the concerns I raised about the ability of pipes to handle varying transient loads, very real.

[123] Entergy's Testimony at A143.
[124] Hopenfeld Prefiled Direct at 10-11, 18-20 (RIV000003); Hopenfeld RK-TC-2 Report at 24-25 (RIV000005).
[125] Entergy's Testimony at A143.

Q. Entergy's witnesses disagree with your position that Entergy has failed to consider how uncertainty related to pipe wall thickness at Indian Point will affect whether components succumb to metal fatigue.[126] Do you have a response to this testimony?

A. Once again, Entergy's witnesses first indicate that they disagree with my testimony because it "presupposes a deficiency in the FAC Program."[127] As discussed above and in my initial testimony and expert report, my testimony has, in fact, demonstrated numerous deficiencies with the program.

Entergy's witnesses next essentially dismiss the concern I have articulated related to metal fatigue, claiming that requirements for calculating fatigue factors do not apply to FAC-susceptible components, and that "stress allowable" of components in the FAC program "are maintained" and that this "adequately protect[s] components against fatigue cracking."[128]

In relation to the potential for FAC to affect primary plant components that are clad with stainless steel that are subject to fatigue, Entergy's witnesses cite to a statement I made in a pleading filed in this proceeding that "I am well aware that stainless steel is not affected by flow accelerated corrosion." However, this statement is cited out of context and the witnesses misrepresent what I was saying. Entergy's witnesses are clearly not familiar with NUREG/CR-6260, *Application of NUREG/CR-5999 Interim Fatigue Curves to Selected Nuclear Power Plant Components* (1995). First, in that statement, I was not discussing balance of plant components, but rather the reactor vessel nozzles, which are part of the reactor coolant system ("RCS"). Second, my comment about the stainless steel cladding was related to the fact that in their fatigue analysis, Entergy used a model of an un-cladded nozzle. In this model, a low alloy steel ("LAS") surface was exposed to high velocity flow making the nozzle susceptible to wall thinning by FAC. The F_{en} equations, which were used to calculate the environmental correction factor, were applicable to LAS, clearly indicating that the model recognized that the LAS was in direct contact with the coolant. Because of the high flow velocities through the nozzle and the LAS material, FAC must be included the fatigue analysis. While I fully discussed Entergy metal fatigue model in testimony that I submitted in this proceeding in support of Riverkeeper

[126] Entergy's Testimony at A144.
[127] *Id.*
[128] *Id.*

Contention TC-1B,[129] I simply note here that it is common in fatigue analysis to assume that the cladding has been breached and to proceed accordingly. In this regard, NUREG/CR-6260 specifies that the effect of the cladding must be considered not from the perspective of its contribution to structural strength, but rather in relation to how it is affected by fatigue.[130] It is apparent that Entergy's witnesses overlooked an important practice in the selection of models for analysis: once a model has been selected, the analysis must be consistent with the underlying assumptions.

It is clear based on the witnesses' response that they do not understand the possible synergy between metal fatigue and FAC. I continue to opine that due to Entergy's flawed FAC program, metal fatigue may become increasingly problematic, and that Entergy has not sufficiently considered this issue.

XI. ***Conclusion***

Q. Please summarize your opinions and conclusions relating to the testimony proffered by Entergy's witnesses relating to Contention RK-TC-2.

A. Entergy's witnesses' testimony does not change my opinion that the effects of aging for FAC-susceptible components at Indian Point will not be adequately managed throughout the period of the extended operation, such that their intended functions will be maintained consistent with the Indian Point current licensing basis ("CLB"), as required by 10 C.F.R. § 54.21(a)(3). Entergy's witnesses' have not provide any supporting evidence that the CLB will be valid throughout the extended period beyond merely stating that the CLB will be maintained. While relevant guidance in the *GALL Report* envisions the use of a reliable, properly benchmarked, bounding predictive code to manage FAC, Entergy employs the use of the CHECWORKS computer model for only a fraction of its FAC program, and to the extent it does, uses a grossly inaccurate model that consistently produces non-conservative results, as acknowledged by Entergy's witnesses. This is completely inconsistent with the *GALL Report*, Revision 2.

[129] *See* Prefiled Direct Testimony of Dr. Joram Hopenfeld Regarding Consolidated Contention NYS-26B/RK-TC-1B – Metal Fatigue (December 20, 2011) (RIV000034); Report of Dr. Joram Hopenfeld in Support of Contention Riverkeeper TC-1B – Metal Fatigue (December 19, 2011) (RIV000035).
[130] NUREG/CR-6260, *Application of NUREG/CR-5999 Interim Fatigue Curves to Selected Nuclear Power Plant Components* (1995) (NYS000355).

Moreover, Entergy has failed to demonstrate that alleged "other tools" Entergy employs are adequate at managing FAC. Entergy has further failed to consider critical safety issues posed by the numerous deficiencies in Entergy's FAC program. In light of the difficulties in predicting component degradation from FAC without a reliable predictive tool, Entergy has not demonstrated the CLB would be maintained during the proposed extended period of operations.

REBUTTAL TO NRC STAFF'S HEARING SUBMISSIONS ON RK-TC-2

Q. NRC Staff's witnesses testify that the CHECWORKS computer code is used "to predict component degradation" and "to identify the most susceptible components for inspection and to calculate wear rates to predict when the components will reach the minimum allowable wall thickness."[131] Do you have any response to this testimony?

A. I agree with NRC Staff's understanding of the appropriate use and function of CHECWORKS. However, this appears to be inconsistent with how Entergy uses the computer model at Indian Point: as "primarily a ranking tool" that "provides a screening and prioritization function."[132] In addition, Entergy's witnesses' testimony makes clear that Entergy only uses CHECWORKS to model susceptible components and predict component degradation for a small fraction of its FAC program.[133] Nowhere in NRC Staff's witnesses' testimony do they discuss an understanding and/or acceptance of using CHECWORKS as purely a ranking/screening tool. In light of this apparent misunderstanding of how Entergy actually uses the CHECWORKS model at Indian Point, I do not believe that NRC Staff's acceptance of Entergy's use of CHECWORKS[134] is well-founded or appropriate.

Q. NRC Staff's witnesses testify that "[t]he future predicted wear rates and thickness values are based on the calibrated models that have been adjusted to reflect the actual wear from the inspection data. In other words, wear rates and wear rate predictions are based on calibration of CHECWORKS™ using actual physical inspection data from

[131] NRC Staff's Testimony at A20, A23, A30.
[132] Entergy's Testimony at A36, A102, A103.
[133] *Id.* at A76, A77, A94.
[134] *See* NRC Staff's Testimony at A31, A52.

components," and further that "[t]his comparison showed that the CHECWORKS™ model accurately predicts FAC behavior."[135] Do you have a response to this position?

A. Once again, it is not clear whether NRC Staff's witnesses understand that at Indian Point, Entergy only models a fraction of susceptible components in CHECWORKS.[136] As a result, NRC Staff's witnesses' acceptance of Entergy's use of CHECWORKS appears mistaken.

In any event, as I discussed above, as well as at length in my initial testimony and expert report, my analysis of data from about five successive outages between 2000 and 2010 at Indian Point Units 2 and 3, clearly demonstrated that CHECWORKS under predicted the actual wear approximately 50% of the time, and by as much as a factor of 10.[137] Notably, while Entergy data is shown as "bounded" by +/-50% lines, above and below a 45° line, that is, 50% conservative and the other 50% non-conservative, a gross split of conservative versus non-conservative numbers is relatively a minor indicator of CHECWORKS performance. A more important indicator, from the safety perspective, is the accuracy of the non-conservative predictions, that is, the degree by which the predictions are underpredicted. At Indian Point, a great deal of the CHECWORKS results underpredicted the component wear by more than a factor of 2. As I discussed above, the manner in which CHECWORKS predictions are presented hides that type of information.[138] By assigning the y-axis as the predicted coordinate and the x-axis as the measured coordinate, the accuracy of the non-conservative data appears to be bound by the -50% line.[139] However, when that arrangement is reversed, it is far clearer that many data points (3 times as many) represent under-predictions of more than a factor of 1.5.[140]

The evidence plainly shows that the code is *not* adequately calibrated, and does *not* accurately predict FAC behavior, at Indian Point. I, therefore, disagree with this testimony.

[135] NRC Staff's Testimony at A20, A23.
[136] *See* Entergy's Testimony at A76, A77, A94.
[137] *See* Hopenfeld Prefiled Direct at 5-10 (RIV000003); Hopenfeld RK-TC-2 Report at 4-13 (RIV000005); *supra* § IV (*The Performance of CHECWORKS at Indian Point*).
[138] *See supra* pp. 24-26.
[139] Hopenfeld, Demonstration of Flawed Presentation of CHECWORKS Data, at Figure 2a (RIV000111).
[140] *Id.* at Figure 2b.

Q. NRC Staff's witnesses testify that when plant operating conditions change, a line correction factor may be applied to adjust wear rate predictions, that is "calibrate" the model, a process NRC Staff's witnesses call "self-benchmarking."[141] Do you have a response to this testimony?

A. Firstly, I disagree with the witnesses' use of the term "self-benchmarking." This term is not appropriate, because it conveys an erroneous message that simply tweaking computer inputs will automatically adjust the model and it will become calibrated.

In any event, once again, my review of actual data from Indian Point has revealed that that notwithstanding the use of line correction factors, the CHECWORKS model is not adequately calibrated at the plant. Moreover, NRC Staff's witnesses, just like Entergy's, testify that there is an "expectation that the model will yield conservative and non-conservative predictions about 50% of the time."[142] As this is apparently an inherent feature of CHECWORKS, the calibration of the code could ostensibly never improve. Thus, NRC Staff's testimony does not appear well-founded. While I do agree with the NRC's Staff's witnesses that "it is not realistic to expect physical inspection data of component thickness to fit the predicted values exactly 100 percent of the time,"[143] I do not agree that it is the intent of the *GALL Report* to allow a significant number of non-conservative predictions to exceed a factor of two and some a factor of ten.

Q. NRC Staff's witnesses disagree with the concerns you articulated about LCFs in the CHECWORKS data at Indian Point.[144] Do you have a response to this?

A. NRC Staff's vague and general testimony does not address the concerns I raised with respect to the arbitrary LCF range employed at Indian Point, or the fact that for many measurements fall outside the allegedly "acceptable" range at the plant. Notably, I am not aware of any NRC statement or explanation that provides an adequate scientific basis for the 0.5-2.5 LCF inspection criteria range.

[141] NRC Staff's Testimony at A24.
[142] *Id.* at A59.
[143] *Id.*
[144] *Id.* at A60.

Q. NRC Staff's witnesses dispute your position that CHECWORKS lacks a track record or performance at Indian Point, and point to your own report as stating that CHECWORKS has been used at Indian Point since at least 2000 and under power uprate conditions.[145] Do you have a response?

A. While it is true that in my expert report I described that CHECWORKS was implemented at Indian Point, I also described at length the various reason why Entergy's use of the model at Indian Point since at least 2000 had been, and continues to be, a complete failure, and not in compliance with relevant standards and guidance. Moreover, simply because various leaks and thinning incidents I cited did not result in a "structural failure"[146] or accident, does not render such events acceptable. As I discussed above and in my initial testimony and expert report, I continue to believe that such instances demonstrate a deficiency in the FAC program at Indian Point.[147]

Q. Overall, NRC Staff's witnesses testify about NRC Staff's approval of Entergy's use of CHECWORKS at Indian Point.[148] Do you have a response to this position?

A. I disagree with the witnesses' assessment that CHECWORKS is acceptable for managing FAC at Indian Point. NRC Staff's witnesses provide no scientific justification for using CHECWORKS as a predictive tool at Indian Point. Nor do NRC Staff's witnesses reveal any indication that NRC Staff has ever commissioned an independent peer review group to evaluate the applicability and efficacy of CHECWORKS at Indian Point. One of the main justifications of the NRC Staff for using CHECWORKS appears to be that "[t]he NRC has long accepted the use of CHECWORKS™ and its predecessor CHEC as important tools to manage FAC. The acceptably of CHECWORKS™ has long existed in the NRC's guidance documents."[149] However, the actual explanation for the NRC accepting CHECWORKS, found in the *GALL Report*, is that CHECWORKS bounds wear predictions conservatively. As I have discussed above, this is not the case at Indian Point, and it should, therefore, not be acceptable to use the

[145] NRC Staff's Testimony at A32.
[146] *Id.*
[147] *See* Hopenfeld Prefiled Direct at 11-12 (RIV000003); Hopenfeld RK-TC-2 Report at 15-18 (RIV000005); *supra* § VII (*Leaks at Indian Point Demonstrate a Defective FAC Program*).
[148] *See* NRC Staff's Testimony at A31, A49-A60.
[149] *Id.* at A31.

1 code there. My initial testimony and expert report provide ample evidence to show that the use
2 of CHECWORKS at Indian Point is misguided and inappropriate.
3
4 **Q. NRC Staff's witnesses testify that "findings of the Board in the *Vermont Yankee***
5 **license renewal proceeding on the FAC contention are applicable to Indian Point."[150] Do**
6 **you agree?**
7 A. No I do not. For the many reasons I already discussed in my initial testimony, expert
8 report, as well as above in response to various statements made by Entergy's witnesses, I believe
9 that the findings of a different licensing board in a difference proceeding are not relevant to
10 whether or not Entergy's program for managing FAC *at Indian Point* during proposed extended
11 operating terms, are irrelevant.[151]
12
13 **Q. NRC Staff's witnesses testify that Entergy's FAC program employs multiple**
14 **"independent" tools, including not just CHECWORKS, but also Indian Point and industry**
15 **operating experience, re-inspections, the non-modeled program, and engineering**
16 **judgment.[152] Do you have a response to this testimony?**
17 A. While this testimony mirrors Entergy's witnesses' claims that other tools are used in the
18 FAC program at Indian Point, it is not clear whether NRC Staff understands that such "other
19 tools" make up that large majority of the FAC program, that is about 75% according to Entergy's
20 witness testimony.
21
22 In any event, based on NRC Staff's witness testimony, it is apparent that the NRC Staff has not
23 performed an adequate check of Entergy's "other tools." Had it done so, it would have found
24 that, while on the surface Entergy's claim sounds impressive, key elements which are required to
25 assess such "other tools" are missing. To meet the regulatory criteria of 10 C.F.R. Part 54 and
26 the *GALL Report*, more than a hollow statement is required. Instead, the applicant must provide
27 enough information to allow the NRC and public to assess the efficacy of such other tools, since
28 scientific uncertainty is inherent in relying on tools that are obviously based in large part on

[150] NRC Staff's Testimony at A41.
[151] *See* Hopenfeld Prefiled Direct at 8-9 (RIV000003); Hopenfeld RK-TC-2 Report at 20-21 (RIV000005); *supra* § VI (*Entergy's Witnesses Inapposite Discussion of and Reliance on Findings Made in Vermont Yankee Proceeding*).
[152] NRC Staff's Testimony at A8, A70.

subjective judgments. The rebuttal testimony I provided above in response to Entergy's witness testimony about Entergy's "other tools" fully describes how Entergy's "other tools" aside from CHECWORKS in the FAC program at Indian Point were not described in sufficient details to allow a thorough assessment of their effectiveness or to draw meaningful conclusions about the validity of their performance.[153]

Q. NRC Staff's witnesses testify that Entergy's FAC program "is consistent with the guidance in the NUREG-1801, Rev. 2, *Generic Aging Lessons Learned (GALL) Report*" and the *GALL Report*, Revision 1.[154] Do you agree?

A. No, I do not, as I have already discussed above in relation to Entergy's witnesses similar conclusion, as well as in my initial testimony and expert report.[155] To briefly reiterate, Entergy's program for managing FAC is not consistent with the guidance in Revisions 1 *or* 2 of the *GALL Report* for several reasons.

First, Revision 2 of the *GALL Report* clearly states that

> CHECWORKS is acceptable because it provides a bounding analysis for FAC. The analysis is bounding because in general the predicted wear rates and component thicknesses are conservative when compared to actual field measurements. It is recognized that CHECWORKS is not always conservative in predicting component thickness; therefore, when measurements show the predictions to be non-conservative, the model must be re-calibrated using the latest field data.[156]

At Indian Point, my analysis of thousands of data points showed that predicted wear rates and component thicknesses *are not* conservative when compared to actual field measurements about 50% of the time. For numerous comparisons, wear was grossly underpredicted by as much as a factor of 10, while most non-conservative measurements were underpredicted by a factor of 1.5. According to the *GALL Report*, because of this circumstance, "the model must be re-calibrated," but this has not, and will not happen at Indian Point. In particular, because decades of apparent

[153] *See supra* § III (Entergy's Reliance on "Other Tools" Apart from CHECWORKS in the Indian Point FAC Program).
[154] NRC Staff's Testimony at A8, A30, A48.
[155] *See* Hopenfeld Prefiled Direct at 16-18 (RIV000003); Hopenfeld RK-TC-2 Report at 25 (RIV000005); *supra* § IX (*Entergy's Failure to Comply with Relevant Regulatory Guidance*).
[156] *GALL Report*, Rev. 2 at § XI.M17 ¶ 5 (NYS00147A-NYS00147D).

1 attempted "recalibration" have not produced a model that yields conservative results, it is
2 unlikely that the model will be able to be adequately recalibrated before, or even during, the
3 proposed periods of extended operation. However, NRC Staff's witnesses (echoing Entergy's
4 witnesses) testify to their *expectation* that CHECWORKS will produce non-conservative
5 predictions about 50% of the time.[157] As Entergy's testimony makes plain, there is no
6 expectation or requirement that Entergy recalibrate the CHECWORKS model to generate
7 conservative results, and, thus, consistency with the *GALL Report* will not be achieved. Notably,
8 CHECWORKS at Indian Point does not produce the "bounding analysis" contemplated by in the
9 *GALL Report*, since the model produces highly inaccurate non-conservative results, as discussed
10 above.[158]
11
12 Furthermore, while the *GALL Report* focuses on the use of CHECWORKS as a quantitative tool
13 to manage FAC: "CHECWORKS or a similar predictive code is used to predict component
14 degradation in the systems conducive to FAC."[159] A FAC programs' central focus on the use of
15 CHECWORKS is also consistent with the guidance in EPRI's Recommendations for an
16 Effective Flow-Accelerated Corrosion Program, NSAC-202L.[160] The *GALL Report* explains that
17 "[i]nspection results are input for a predictive computer code, such as CHECWORKS, to
18 calculate the number of refueling or operating cycles remaining before the component reaches
19 the minimum allowable wall thickness."[161] In contrast, as the testimony from Entergy's
20 witnesses makes clear and as I discussed above, CHECWORKS is only used at Indian Point for a
21 fraction of the FAC management program, and primarily to rank components and establish
22 inspection priorities, and not as contemplated in the *GALL Report*.[162]
23
24 Moreover, as discussed in my initial testimony, and in my discussion above of Entergy's alleged
25 "other tools" for managing FAC, it remains my professional opinion that Entergy has yet to

[157] NRC Staff's Testimony at A59.
[158] *See* Hopenfeld, Demonstration of Flawed Presentation of CHECWORKS Data at Figures 2a, 2b (RIV000111).
[159] *GALL Report*, Rev. 1 at § XI.M17 (NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 (NYS00147A-NYS00147D).
[160] EPRI, Recommendations for an Effective Flow-Accelerated Corrosion Program, NSAC-202L-R3 (RIV000012).
[161] *GALL Report*, Rev. 1 at § XI.M17 ¶ 6(NYS00146A-NYS00146C); *GALL Report*, Rev. 2 at § XI.M17 ¶ 6 (NYS00147A-NYS00147D).
[162] *Supra* at pp. 10, 11.

provide sufficiently detailed information to ensure its program is consistent with all elements discussed in the *GALL Report*.[163]

It is shocking to me that even though NRC Staff conducted several audits at Indian Point, they do not comprehend how inconsistent the FAC program is with the *GALL Report*.

Q. Please summarize your opinions and conclusions relating to the testimony proffered by NRC Staff's witnesses relating to Contention RK-TC-2.

A. I disagree with NRC Staff's witnesses' conclusions that Entergy's program for managing FAC during the proposed periods of extended operation is adequate.

Importantly, it appears that NRC Staff have based their determination about the adequacy of Entergy's FAC AMP on incorrect information. In particular, the testimony submitted by Entergy in this proceeding on March 28, 2012, has revealed new information about Entergy's FAC program that is substantially and materially different then what was described in the LRA and the SER: contrary to the explanation in the LRA that Entergy's FAC program was based on the *GALL Report* and NSAC-202L, both of which focus on the use of a quantitative predictive code, Entergy has now revealed that CHECWORKS informs but a fraction of its FAC inspection program. Since Entergy's modifications of its original FAC program go to the heart of Entergy's AMP, the NRC Staff's assessment and conclusions about Entergy's FAC program in the Indian Point SER, as well as in the NRC Staff's witness testimony, must be reevaluated to more accurately reflect the program and its compliance with relevant guidance.

Furthermore, NRC Staff fails to recognize how Entergy's FAC program is fundamentally inconsistent with Revision 2 of the *GALL Report*, which requires that CHECWORKS be recalibrated if it produces non-conservative results, a circumstance that is impossible to achieve at Indian Point, and that NRC Staff's witnesses actually appear to approve.

[163] *See supra* § III (Entergy's Reliance on "Other Tools" Apart from CHECWORKS in the Indian Point FAC Program).

NRC Staff's witnesses appear to endorse Entergy's FAC program by essentially restating previous Entergy statements about the program at Indian Point. My review of NRC Staff's hearing submissions did not reveal any independent NRC Staff analysis of key FAC issues at Indian Point, such as, locations for inspections, accuracy of wall thickness predictions, inspection frequencies, or the efficacy of CHECWORKS at the plant. NRC has raised many arguments identical to those of Entergy, which, for the reasons I discussed in my initial testimony and expert report, as well as in the above rebuttal to Entergy's witness testimony, do not resolve the concerns raised in Contention RK-TC-2.

Overall, NRC Staff's witnesses' testimony does not change my opinion that the effects of aging on FAC-susceptible components at Indian Point will not be adequately managed throughout the period of the extended operation, such that their intended functions will be maintained consistent with the Indian Point CLB, as required by 10 C.F.R. § 54.21(a)(3).

Q. Does this conclude your rebuttal testimony regarding Riverkeeper Contention RK-TC-2?

A. Yes.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
Entergy Nuclear Operations, Inc.	)	Docket Nos.
(Indian Point Nuclear Generating	)	50-247-LR
Units 2 and 3)	)	and 50-286-LR
	)	

DECLARATION OF DR. JORAM HOPENFELD

I, Joram Hopenfeld, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Executed in Accord with 10 C.F.R. § 2.304(d)

Joram Hopenfeld

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