UNITED STATES

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In re:	Docket Nos. 50-247-LR; 50-286-LR
License Renewal Application Submitted by Entergy Nuclear Indian Point 2, LLC, Entergy Nuclear Indian Point 3, LLC, and Entergy Nuclear Operations, Inc.	ASLBP No. 07-858-03-LR-BD01 DPR-26, DPR-64 September 9, 2015

PRE-FILED WRITTEN SUPPLEMENTAL REPLY TESTIMONY OF

DR. DAVID J. DUQUETTE

REGARDING CONTENTION NYS-38 / RK-TC-5

On behalf of the State of New York ("NYS" or "the State"), the Office of the Attorney General hereby submits the following rebuttal testimony by David J. Duquette, Ph.D. regarding Contention NYS-38/RK-TC-5.

Q. Please state your full name.

A. David J. Duquette.

Q. What is the purpose of this testimony you are now providing?

A. I have previously provided testimony in this proceeding regarding primary water stress corrosion cracking

(PWSCC) in steam generators and the need for baseline inspections of the Indian Point steam generator divider plate assemblies, tube-to-tubesheet welds, and channel head assemblies prior to license renewal. (NYS000372, NYS000373, NYS000452, NYS000532). This testimony supplements, and incorporates by reference, my prior testimony in this proceeding.

Q. I show you what has been marked as Exhibit ENT000699. Do you recognize that document?

A. Yes. It is a copy of the pre-filed testimony of the witnesses for Entergy on Contention NYS-38/RK-TC-5 that were submitted in August 2015.

Q. I show you what has been marked as Exhibit NRCR000161, NRC000197 and NRC000168. Do you recognize those documents?

A. Yes. They are copies of the pre-filed testimony of NRC Staff witnesses that were submitted in August 2015. They concern Contention NYS-38/RK-TC-5. I note that NRC000168 and NRC000197 primarily address Contentions NYS-25 and NYS-26B/RK-TC-1B.

Q. Have you had an opportunity to review ENT000699, NRCR000161, NRC000168, and NRC000197?

A. Yes.

Q. Has Entergy's and NRC Staff's August pre-filed testimony caused you to change the testimony and opinions that you have previously submitted in this proceeding in connection with Contention NYS-38?

A. No. It is still my opinion that Entergy should perform visual baseline inspections of the eight Indian Point steam generators prior to license renewal, that is, before Entergy receives renewal 20-year operating licenses for Indian Point Unit 2 and Unit 3.

Q. Does Entergy currently perform inspections of the steam generators?

A. It is my understanding that Entergy currently performs periodic visual inspections of the steam generator bowls, tubesheets, and plugs using remote camera techniques. Entergy Testimony at A175 (ENT000699). Entergy could readily expand the scope of those inspections to include the divider plate assemblies and the tube-to-tubesheet welds.

Q. What is Entergy's position with respect to performing divider plate and tube-to-tubesheet weld inspections?

A. It is non-committal, at present. Although Entergy committed to inspect for PWSCC in the IP2 and IP3 steam generator divider plates as part of Commitment 41 (see, NL-11-

074, Attach. 1 at 14 (NYS000152), its most recent testimony confirms that the company is considering retraction of that commitment in light of [redacted]

Entergy had also committed, via Commitment 42, to address PWSCC in tube-to-tubesheet welds by either performing inspections of those steam generator component locations, or by demonstrating through analyses that they are not susceptible to PWSCC or are not part of the reactor coolant boundary. NL-11-032, Attach. 1 at 22-23 (NYS000151); NL-11-074, Attach. 2 at 15 (NYS000152).

Q. What is the current status of Commitment 42?

A. In late 2014, Entergy redefined the reactor coolant pressure boundary so as to exclude tube-to-tubesheet weldments

at the IP2 steam generators. NYS000542. Apparently, Entergy considers Commitment 42 fulfilled as to IP2. NYS000553.

Q. How is Entergy proposing to fulfill Commitment 42 for IP3 steam generator tube-to-tubesheet welds?

A. Entergy has indicated that it prefers the "analysis" option over the "inspection" option for IP3, and is currently evaluating whether [redacted] Entergy Testimony at A166 (ENT000699).

Q. To your knowledge, have the IP2 and IP3 steam generator divider plates and tube-to-tubesheet welds ever been inspected for PWSCC?

A. No, I do not believe they have ever been inspected. In its testimony, Entergy does not mention any previous inspections of these components and locations. Moreover, given Entergy's support for [redacted] and the company's stated preference for analysis rather than inspection, those components/locations may never be inspected.

Q. Do you have any concerns about Entergy's reliance on [redacted] as a basis to retract Commitment 41 and/or close Commitment 42?

A. As I have previously indicated, I do not believe the results of EPRI's investigations into steam generator component cracking eliminate the need for actual inspections at Indian Point. To the contrary, [redacted] Entergy Testimony at A188 (ENT000699).

As an initial matter, I would like to emphasize that [redacted]

[redacted]

By this standard, Entergy has not shown that the chromium contents of its divider plates and tube-to-tubesheet welds are sufficient to mitigate PWSCC initiation. For example, Entergy acknowledges that IP2 and IP3 steam generator divider plates are constructed of Alloy 600 with Alloy 82/182 cladding, a low-chromium combination that leaves the component vulnerable to PWSCC.

Alloy 600 has a nominal chromium content of 14 to 17 wt.%, while the welding alloys, 182 and 82, have chromium contents of 13 to 17 wt.% and 18 to 22 wt.% respectively. [redacted] Any combination of Alloy 600, Alloy 182, and Alloy 82 therefore would result in a combined chromium content of less than [redacted] Accordingly, the cladding of the alloy steel tubesheet, the divider plate and the divider plate-to-tubesheet cladding welds are all, [redacted] susceptible to PWSCC initiation, independent of the ratio of ratio of the Alloy 82/182 in the cladding or weldments (the ratios of these alloys in the cladding and in the weldments are apparently unknown).

Q. Please discuss the chromium content of the tube-to-tubesheet welds at Indian Point.

A. The chromium content of a tube-to-tubesheet weld –- and therefore its resistance to PWSCC -- depends on the type of tube (Alloy 600 vs.690) and the tubesheet cladding (Alloy 82 vs. 182) involved in the weldment. [redacted]

[redacted]

[redacted]

[redacted]

Q. Do the Indian Point tubesheets contain Alloy 82 and Alloy 182 cladding?

A. Yes. Entergy acknowledges the presence of both Alloy 82 and Alloy 182 cladding on its tubesheets, and has not disputed [redacted]

Q. How does this affect the PWSCC susceptibility of tube-to-tubesheet welds at Indian Point?

A. The IP2 steam generators utilize Alloy 600 tubes and Alloy 82/182 tubesheet cladding. [redacted] Thus, all of the tube-to-tubesheet welds at IP2 are potentially susceptible to PWSCC based on reduced chromium content.

For IP3 steam generators, [redacted] that a significant number of tube-to-tubesheet welds also lack sufficient chromium levels to mitigate PWSCC initiation. [redacted] The IP3 steam generators utilize higher chromium content Alloy 690TT tubing. However, the chromium content of welds is diluted through the lower chromium-containing Alloy 82/182 tubesheet cladding. [redacted]

[redacted]

Entergy Testimony at A188 (ENT000699). His suggestion that the IP3 tube-to-tubesheet welds have sufficient chromium content to mitigate PWSCC is therefore misleading.

Q. [redacted] Do you agree with this assessment?

A. No. [redacted]

[redacted]

initiation or propagation of cracks in the tubesheet, cladding or tube-to-tubesheet welds. [redacted]

[redacted]

If a crack does initiate in any region of residual tensile stresses, the leading edge of a crack is a stress intensifier, locally increasing the tensile stresses. Thus, once a crack initiates, it has an autocatalytic nature that tends to increase the crack propagation rate (longer cracks grow faster in a constant global stress field). [redacted]

[redacted] For example, if a crack initiates in the divider plate assembly or tube-to-tubesheet welds, and propagates through the cladding to the tubesheet, corrosion of the alloy steel tubesheet may occur during periods when the divider plate assembly and the steam generator bowl are exposed to air and water (maintenance periods). For example, the wastage observed in the channel head bowl drain at Wolf Creek illustrates the type and extent of corrosion that may occur notwithstanding the presence of cladding intended to prevent corrosion or cracking of components exposed to water. Westinghouse Nuclear Safety Advisory Letter 12-1 (NYS000549).

Corrosion of alloy steels results in corrosion products that are considerably more voluminous than the alloy from which they are produced. This is especially important since the tubesheets are known to undergo cyclic loading (fatigue).

[redacted]

Entergy Testimony at A189, A199. However, if corrosion occurs at the leading edges of primary water stress corrosion cracks, the local environment will be in tension due to the expansion created by the corrosion product and fatigue cracks will be free to propagate under local tensile stresses.

Q. Can PWSCC affect the growth of cracks initiated by fatigue?

A. Cracking can occur as a result of fatigue or PWSCC, or a combination of the two (sometimes expressed as stress corrosion fatigue). A crack that originates by fatigue can propagate by PWSCC, just as a crack that originates by PWSCC can propagate by fatigue. Notably, Westinghouse's fatigue analysis for the IP3 divider plates indicates that [redacted] (ENT000683). This indicates

that [redacted] Prompt inspection of the divider plate assemblies and other components of Indian Point's aging steam generators would afford early detection of cracks resulting from fatigue, PWSCC or a combination of fatigue and PWSCC.

Q. Do you have closing remarks?

A. Both domestic and foreign operational experience indicate that nuclear system components experience corrosion, cracking and/or other modes of degradation and failure, particularly within the context of aging fleets, despite models, calculations, simulations and/or projections that would indicate otherwise. These include failures of piping, steam generator tubes, corrosion of clad steels, cracking of divider plate

assemblies, etc. Entergy's own expert, Barry M. Gordon, in a recent article on corrosion in light water reactors (BWR's and PWR's), stated: "Although corrosion was somewhat considered in both plant designs, corrosion was not considered as a serious concern...The problem was that the 'qualifying' laboratory tests did not necessarily reproduce the reactor operating conditions (e.g., especially the high residual tensile stresses from welding and cold work) and the test times were of short duration relative to the initial plant design lifetime of 40 years, which is currently being extended to 60 to 80 years. For example, the initiation time for environmentally-assisted cracking (EAC), i.e., primary water stress corrosion cracking (PWSCC) of nickel-base alloys in PWRs, which is the primary corrosion concern is this design LWR, can be a long as 25 years! [sic]" See, B.M. Gordon, "Corrosion and Corrosion Control in Light Water Reactors," Journal of Metals, Vol. 65, Issue 8, August 2013 at 5 (ENT000713). The following table is an excerpt from Gordon's Table I entitled "Partial Summary of the Corrosion History of LWRs" (id. at 6), and indicates the myriad problems of unexpected corrosion-related events encountered in the PWR fleet:

Corrosion Event	Time of Detection
Alloy 600 IGSCC in a laboratory study	Late 1950's
IGSCC in U-bend region of PWR steam generator	Early 1970s
Denting of PWR Alloy 600 steam generator tubing	Mid 1970s
PWSCC of PWR Alloy 600 steam generator tubing	Mid 1970s
PWSCC in PWR pressurizer heater sleeves	Early 1980s
General corrosion of carbon steel containments	Early 1980s
FAC of single phase carbon steel systems in PWRs	Mid 1980s
PWSCC in PWR pressurizer instrument nozzles	Late 1980s
Axial PWSCC of Alloy 600 of PWR top head penetration	Early 1900s
Circumferential PWSCC of j-groove welds	Early 1900s
PWSCC of PWR hot leg nozzle Alloy 182/82	Early 2000s
PWSCC induced severe boric acid corrosion of a PWR head	Early 2000s
SCC of stainless steels in PWRs	Early 2000s

Given this history of unpredicted corrosion events, the use of laboratory simulations and computational approaches to predict the performance of the divider plate assemblies and associated steam generator components is problematic at best. In my opinion, baseline inspections with follow-up periodic

inspections of steam generators are the only effective means to ensure that unexpected cracks or defects neither occur, nor otherwise grow undetected to become failures.

As I previously testified, I believe Entergy should affirmatively and clearly commit to performing inspections as soon as possible for IP2, and certainly before the period of extended operation for IP3. Instead of inspecting "representative welds" Entergy should specifically target tube-to-tubesheet welds in areas where [redacted] Additionally, Entergy should identify the inspection techniques it intends to use, develop acceptance criteria, and provide a detailed plan for addressing any flaws or indications that it may encounter. Follow-up inspections should be performed at least every 10 years, given the primarily Alloy 600 construction of IP2 steam generator components and assemblies and the age of the IP3 steam generators.

In 2011, as part of this relicensing proceeding, Entergy "conservatively committed to confirm the absence of PWSCC indications during the PEO." Entergy Testimony at A147 (ENT000699). NRC should condition license renewal upon Entergy fulfilling that commitment.

Finally, I reserve the right to supplement my testimony if new information is disclosed or introduced.

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DECLARATION OF DAVID J. DUQUETTE

I, David J. Duquette, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal 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)

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