

In the Matter of: Entergy Nuclear Operations, Inc.  
(Indian Point Nuclear Generating Units 2 and 3)

**NYS000571 (Public, Redacted)**  
**Submitted: September 9, 2015**



ASLBP #: 07-858-03-LR-BD01  
Docket #: 05000247 | 05000286  
Exhibit #: NYS000571-PUB-00-BD01  
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**UNITED STATES**

**NUCLEAR REGULATORY COMMISSION**

**BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

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

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**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

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

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

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

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

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

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

21 A. Yes.

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

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

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

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

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

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

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

[REDACTED]

12 [REDACTED]

13 Entergy had also committed, via Commitment 42, to address  
14 PWSCC in tube-to-tubesheet welds by either performing  
15 inspections of those steam generator component locations, or by  
16 demonstrating through analyses that they are not susceptible to  
17 PWSCC or are not part of the reactor coolant boundary. NL-11-  
18 032, Attach. 1 at 22-23 (NYS000151); NL-11-074, Attach. 2 at 15  
19 (NYS000152).

20 Q. What is the current status of Commitment 42?  
21 A. In late 2014, Entergy redefined the reactor coolant  
22 pressure boundary so as to exclude tube-to-tubesheet weldments

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

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

5 A. Entergy has indicated that it prefers the "analysis"  
6 option over the "inspection" option for IP3, and is currently  
7 evaluating whether [REDACTED]

8 [REDACTED]  
9 [REDACTED] Entergy Testimony at A166 (ENT000699).

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

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

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

1           A.    As I have previously indicated, I do not believe the  
2 results of EPRI's investigations into steam generator component  
3 cracking eliminate the need for actual inspections at Indian  
█ Point. To the contrary, █

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17           █ Entergy Testimony at A188 (ENT000699).  
█ As an initial matter, I would like to emphasize that █

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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[REDACTED]

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By this standard, Entergy has not shown that the chromium

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contents of its divider plates and tube-to-tubesheet welds are

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sufficient to mitigate PWSCC initiation. For example, Entergy

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acknowledges that IP2 and IP3 steam generator divider plates are

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constructed of Alloy 600 with Alloy 82/182 cladding, a low-

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chromium combination that leaves the component vulnerable to

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PWSCC.

1 Alloy 600 has a nominal chromium content of 14 to 17 wt.%,  
2 while the welding alloys, 182 and 82, have chromium contents of  
3 13 to 17 wt.% and 18 to 22 wt.% respectively. [REDACTED]

4 [REDACTED] Any combination of Alloy 600, Alloy 182, and  
5 Alloy 82 therefore would result in a combined chromium content  
6 of less than [REDACTED] Accordingly, the cladding of the alloy  
7 steel tubesheet, the divider plate and the divider plate-to-  
8 tubesheet cladding welds are all, [REDACTED]

9 [REDACTED] susceptible to PWSCC  
10 initiation, independent of the ratio of ratio of the Alloy  
11 82/182 in the cladding or weldments (the ratios of these alloys  
12 in the cladding and in the weldments are apparently unknown).

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

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

[REDACTED]

[REDACTED]

[REDACTED]

22 [REDACTED]



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

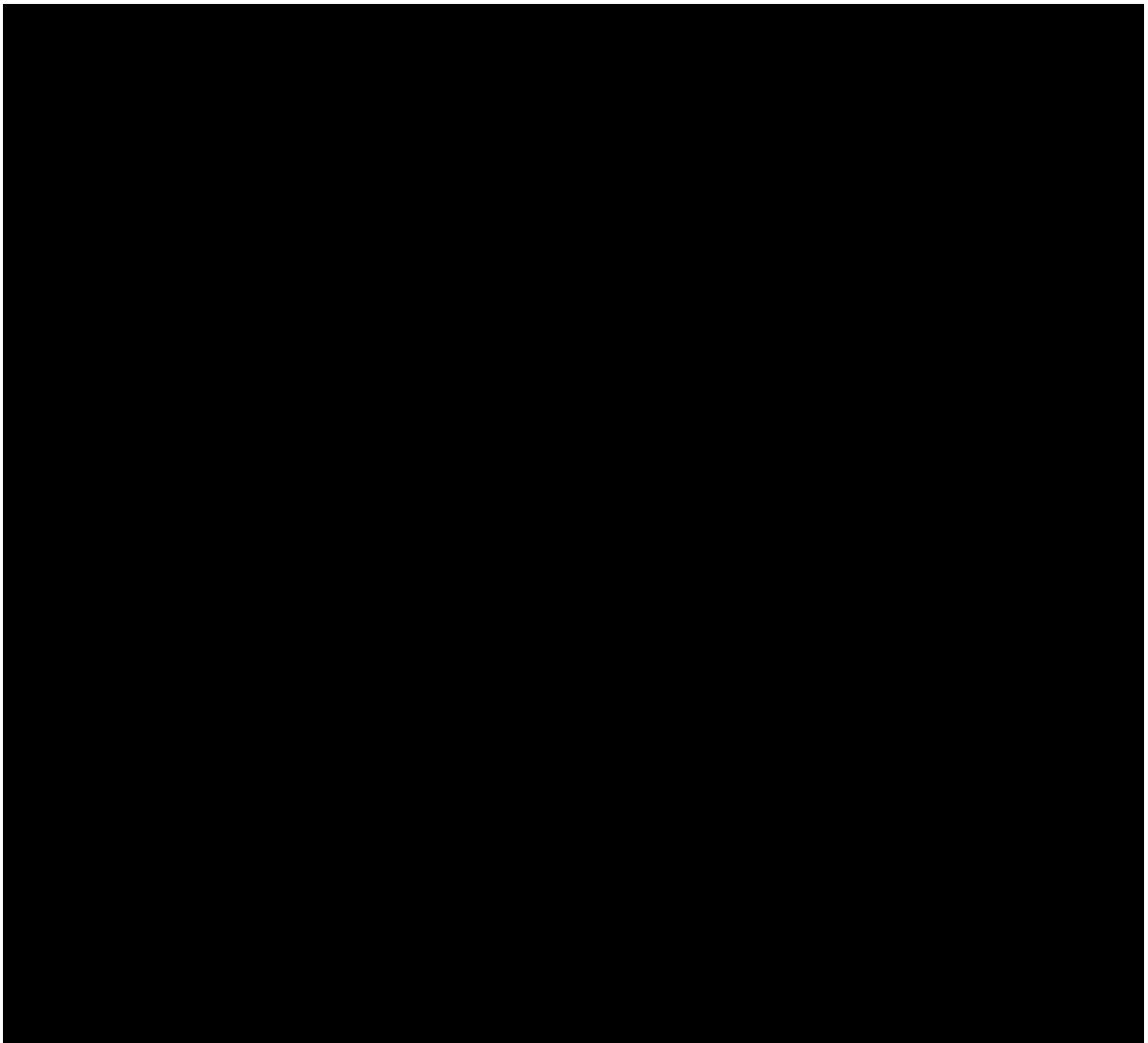
[REDACTED]

[REDACTED]

[REDACTED]

8 [REDACTED]

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Q. Do the Indian Point tubesheets contain Alloy 82 and

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Alloy 182 cladding?

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A. Yes. Entergy acknowledges the presence of both Alloy

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82 and Alloy 182 cladding on its tubesheets, and has not

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disputed



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

3 A. The IP2 steam generators utilize Alloy 600 tubes and  
4 Alloy 82/182 tubesheet cladding. [REDACTED]

5 [REDACTED]  
6 [REDACTED]  
7 [REDACTED]  
8 [REDACTED]  
9 [REDACTED] Thus, all of the tube-to-tubesheet welds at IP2  
10 are potentially susceptible to PWSCC based on reduced chromium  
11 content.

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

20 [REDACTED]  
21 [REDACTED]

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[REDACTED]

[REDACTED]

[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]

[REDACTED] Do you agree  
with this assessment?

A. No. [REDACTED]

*Pre-filed Written  
Supplemental Reply Testimony  
of David J. Duquette  
Contention NYS-38/RK-TC-5*

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

[REDACTED]

4 [REDACTED]

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

[REDACTED]

12 [REDACTED] For example, if a crack initiates  
13 in the divider plate assembly or tube-to-tubesheet welds, and  
14 propagates through the cladding to the tubesheet, corrosion of  
15 the alloy steel tubesheet may occur during periods when the  
16 divider plate assembly and the steam generator bowl are exposed  
17 to air and water (maintenance periods). For example, the  
18 wastage observed in the channel head bowl drain at Wolf Creek  
19 illustrates the type and extent of corrosion that may occur  
20 notwithstanding the presence of cladding intended to prevent  
21 corrosion or cracking of components exposed to water.

22 Westinghouse Nuclear Safety Advisory Letter 12-1 (NYS000549).

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

5 [REDACTED]  
6 [REDACTED]  
7 Entergy Testimony at A189, A199. However, if corrosion occurs at  
8 the leading edges of primary water stress corrosion cracks, the  
9 local environment will be in tension due to the expansion  
10 created by the corrosion product and fatigue cracks will be free  
11 to propagate under local tensile stresses.

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

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

20 [REDACTED]  
21 [REDACTED]  
22 [REDACTED] (ENT000683). This indicates



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

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**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 1990s
Circumferential PWSCC of j-groove welds	Early 1990s
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

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

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

4 As I previously testified, I believe Entergy should  
5 affirmatively and clearly commit to performing inspections as  
6 soon as possible for IP2, and certainly before the period of  
7 extended operation for IP3. Instead of inspecting  
8 "representative welds" Entergy should specifically target tube-  
to-tubesheet welds in areas where [REDACTED]

[REDACTED]  
[REDACTED]  
11 [REDACTED] Additionally, Entergy should identify the  
12 inspection techniques it intends to use, develop acceptance  
13 criteria, and provide a detailed plan for addressing any flaws  
14 or indications that it may encounter. Follow-up inspections  
15 should be performed at least every 10 years, given the primarily  
16 Alloy 600 construction of IP2 steam generator components and  
17 assemblies and the age of the IP3 steam generators.

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

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

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

A handwritten signature in black ink, appearing to read "D.J. Duquette", is written over a horizontal line. The signature is cursive and somewhat stylized.

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David J. Duquette, Ph.D.  
Materials Engineering Consulting Services  
4 North Lane  
Loudonville, New York 12211  
Tel: 518 276 6490  
Fax: 518 462 1206  
Email: duqued@rpi.edu  
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