UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
Before the Atomic Safety and Licensing Board

In the Matter of	)	
		Docket No. 50-346-LR
First Energy Nuclear Operating Company	)	
(Davis-Besse Nuclear Power Station, Unit 1)		July 23, 2012
	)	

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<u>INTERVENORS' FOURTH MOTION TO AMEND AND/OR SUPPLEMENT PROPOSED CONTENTION NO. 5 (SHIELD BUILDING CRACKING)</u>

Now come Beyond Nuclear, Citizens Environment Alliance of Southwestern Ontario (CEA), Don't Waste Michigan, and the Green Party of Ohio (collectively, "Intervenors"), by and through counsel, and move the Board for leave to further supplement and amend their proposed Contention No. 5, which addresses the shield building cracking phenomena at the Davis-Besse Nuclear Power Station ("Davis-Besse"). This supplementation focuses on a new collection of information recently added to the ADAMS library, namely, the report of Performance Improvement International on the Davis-Besse shield building cracking. That report was added to ADAMS on May 24, 2012.

A. Background

On January 10, 2012, Intervenors moved for admission of a new Contention No. 5, which states:

> Intervenors contend that FirstEnergy's recently-discovered, extensive cracking of unknown origin in the Davis-Besse shield building/secondary reactor radiological containment structure is an aging-related feature of the plant, the condition of which precludes safe operation of the atomic reactor beyond 2017 for any period of time, let alone the proposed 20-year license period.

The NRC Staff ("Staff") has proposed alternative wording which would transform the contention

into a contention of omission. FirstEnergy Nuclear Operating Company ("FENOC") and the Staff timely responded to the original contention motion.

On February 28, 2012, First Energy Nuclear Operating Company ("FENOC") furnished the NRC with its "Root Cause Analysis Report" ("Root Cause Analysis" or "RCA"), ML120600056. Then, on April 5, 2012, FENOC promulgated an "aging management plan", or AMP (ML12097A216), the purpose of which is to specify arrangements prospectively to oversee and deal with the shield building's historic cracking phenomena.

Intervenors moved on July 16, 2012 to supplement their cracking contention for the purpose of exposing discrepancies between FENOC's May 16, 2012 Revised "Root Cause Analysis Report" ("RRCA"), and other analyses of the shield building problems. In that July 16, 2012 filing, Intervenors indicated that by July 23, 2012, they would file an additional motion which demonstrated inconsistencies between FENOC's February 2012 Root Cause Analysis and the findings of FENOC's consultant, Performance Improvement International. PII's report, "Root Cause Assessment: Davis-Besse Shield Building Laminar Cracking, Vol. 1," was added to the NRC's ADAMS system on May 24, 2012 as ML12138A037 , which is one of multiple volumes of PII analysis added to ADAMS that day. Intervenors are timely acting to itemize the divergences and issues of fact between the proposed license action and the true status of the Davis-Besse shield building by making this filing within the 60 day period set forth in the Initial Scheduling Order in this case.[1]

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[1]From p. 12 of Initial Scheduling Order, ASLBP No. 11-907-01-LR-BD01 (June 15, 2011): "The Board directs that a motion and proposed new contention shall be deemed timely under 10 C.F.R. § 2.309(f)(2)(iii) if it is filed within sixty (60) days of the date when the material information on which it is based first becomes available to the moving party through service, publication, or any other means. If filed thereafter, the motion and proposed contention shall be deemed nontimely under 10 C.F.R. §

Intervenors maintain that there is serious incongruity between the cracking problems as defined by FENOC, and the proposed remedy, exemplified by the AMP. The scope of the admitted cracking is far narrower than the identified cracking, and the potential for further concrete and rebar problems in the Davis-Besse shield building may include the loss of up to 90% of the shield building walls with the collapse of outer layers of concrete and rebar, according to NRC documents.

B. Issues of Fact And Inconsistencies Between Root Cause Analysis And Performance Improvement International's Assessment

Although Performance Improvement International's (PII) revised root cause assessment report ("PII report") is dated April 20, 2012, it was not communicated to the U.S. Nuclear Regulatory Commission (NRC) until May 14, 2012 (attached to a cover letter by FENOC's Barry Allen), and was not publicly posted to NRC's ADAMS cache until May 24, 2012.

Barry Allen claimed in a May 16, 2012 cover letter to NRC, attached to FENOC's own revised root cause report ("RCA"), that any changes required of FENOC by NRC upon its review of FENOC's Feb. 28, 2012 root cause report were minor and did not significantly affect any findings or conclusions. But the changes and revelations prompted by statements appearing on pp. i-iv[2] of PII's report are quite significant. PII listed 27 revisions, each associated with NRC questioning, in a section entitled "Summary of Revisions in Version 2. "

At p. i, PII relates NRC's first question:

> 1. Item 15: Were fracture surfaces or concrete voids tested near the subsurface laminar crack surfaces for the presence [of] Ettringite as was done along the outer surface of the SB [Shield Building] core bores to confirm moisture intrusion (e.g. Ettringite)? If not,

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2.309(c). If the movant is uncertain, it may file pursuant to both sections."

[2]Pp. 17-20/257 of PII report .pdf

why was this test not done to confirm that moisture had penetrated to location/depth of laminar cracks? If this testing was done provide the results.

In response, PII added to F.M. [Failure Mechanism] 3.9 - Discussion - Moisture Migration, the following:

> Moisture Migration
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> The WJE report (Exhibit 26) provides physical evidence of moisture migration uniformly through the concrete for the full depth of the cores (over 4 inches). The thin layer of secondary deposits after 40 year exposure is not considered an indication of attack since it does not create any stresses or strength reduction. The presence of deposits is not considered a strong indicator of moisture migration that should be pursued further with tests for Ettringite presence - especially since no environmental Sulfates were suspected. Ettringite may be present in concrete pores at different time periods and for different reasons, including sulfate attack and normal internal reactions.
>
> General Chemical Attack
>
> 1. Exhibit 23 presents a list of chemicals known to have a deleterious effect on concrete. None of those chemicals is known to be present in significant quantities in contact with the concrete containment structure.
>
> Conclusion:
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> The containment structure's concrete did not undergo chemical attack. Therefore, chemical attack was not a contributor to the Laminar Cracks. Specifically, carbonation depth is small comparing with the thickness of concrete cover for the 40-year old structure, and carbonation-induced steel corrosion is not a root cause.

While PII makes qualitative, deductive arguments, which it then asserts as proof of shield building integrity, these are not backed up by empirical data. For example, "physical evidence of moisture migration uniformly through the concrete for the full depth of the cores (over 4 inches)" would seem to indicate that the outer layer of rebar, located under 3 inches of exterior concrete, has been overtaken by moisture over the life of the shield building. Such moisture interaction with the steel reinforcement would have provided a corrosive environment. Corrosion of rebar could have contributed to shield building cracking.

PII further asserts "no environmental Sulfates were suspected," and provides "a list of

chemicals known to have a deleterious effect on concrete" but claims "None of those chemicals is known to be present in significant quantities in contact with the concrete containment structure." One would expect that if PII or any other FENOC contractor has actually tested for environmental sulfates, or other "chemicals known to have a deleterious effect on concrete," in order to determine if they are "present in significant quantities in contact with the concrete containment structure", such information would be disclosed. It appears that no actual tests have been performed, rendering this conclusion scientifically suspect.

Given FENOC's and NRC's disclosures of chronic groundwater leakage within the sand pocket region between the shield building and the steel containment vessel, documented in 2011 RAIs and responses thereto, the lack of testing for environmental sulfates or other aggressive chemicals capable of attacking the shield building's concrete is a significant, unacceptable omission from the FENOC ER. Such unchecked chemical attack, besides comprising a potential, yet unaddressed, root cause of shield building degradation, could also worsen cracking and other shield building degradation, an aging-related failure mechanism that is not as yet addressed within this license extension proceeding.

Finally, PII implies that below a "significant quantity" threshold, aggressive chemicals could not cause chemical attack on the shield building. But, as U.S. Congressman Dennis Kucinich communicated to NRC Chairman Greg Jaczko in November, 2011, even cracks of very narrow width could enable carbon dioxide from the atmosphere to initiate a carbonation degradation of shield building structures. Congressman Kucinich's concerns were based on a study carried out at Oak Ridge nuclear lab.

PII related a second NRC question:

> 2. Item 19: Why did the observed laminar cracking propagate "through" the coarse aggregate instead of around the aggregate? Does this suggest any information about the rate of crack propagation?

In response, PII added to Section 2.01 - Laboratory Tests and Examination to Test for Concrete Integrity (1st paragraph, p. 3) the following:

> Furthermore, examination of the core bores revealed that the cracks propagated through the aggregate which demonstrates a strong bond between the cement paste and aggregate. The propagation of cracks through aggregates is common in mature concrete. In cases like this one, the location and direction of the stresses and resultant cracks is predetermined and, depending on the orientation of the aggregates, may make propagation through the aggregate the 'path of least resistance'. It is possible that propagation through the aggregate requires less energy than through the interface around it. This cracking through the aggregate does not provide any reliable information about the rate of crack propagation.

First, while theories of "path of least resistance" crack propagation may seem to make common sense, Intervenors hold that arguments forming the basis for a 20- year license extension at an atomic reactor with a severely cracked shield building of still-mysterious causation should be subjected to rigorous scientific review, not mere common sense assertions. The uncertainty is self-evident in PII's statement "It is possible that propagation through the aggregate requires less energy than through the interface around it." No explanation is given by PII, nor FENOC for that matter, as to why such hypotheses have not been subjected to rigorous scientific review. Such a rigorous review could be provided by a hearing on the merits of the shield building cracked concrete contention.

Second, PII's admission that "This cracking through the aggregate does not provide any reliable information about the rate of crack propagation" is disconcerting, because ignorance of whether cracks are worsening, and how fast such crack propagation is proceeding, represents an unacceptable blind spot to risk over a 20-year license extension period. This is the precise kind of dynamic which FENOC and its contractors like PII should be assessing, given the potential for worsening cracking, and consequent worsening safety risks, over the 2017-2037 time frame.

PII related a third question from NRC:

> 3. Item 20: With the conclusion that the laminar subsurface cracking was not exposed to air, what caused the trace amounts of carbonation identified on the transverse and longitudinal crack surfaces?

PII's response contains some troubling admissions. In its *"Carbonation Failure Mode"* section, PII admits:

> In some locations, cover to outer surface of rebar was found to be as low as 1 inch (25.4mm). This reduced cover is likely the result of exceptional conditions (such as reinforcement overlaps, bundling, or misaligned forms)

Only 1 inch of concrete cover over the underlying outer layer of reinforcing steel increases the vulnerability of the rebar to such degradation as moisture induced corrosion, as well as carbonation. Either case could cause or worsen shield building cracking.

PII also offers a weak explanation of the carbonation results. It attempts to dodge addressing the significance of carbonation on core bores by claiming that once extracted, "exposure to air prior to testing" could have caused the evident carbonation (see bullet #2 on page 4). PII and FENOC need to develop better testing methods. Testing methods should not destroy the subject matter being studied, rendering all results meaningless. This is a very poor scientific, technical, and engineering basis upon which to establish a sound 20-year license extension at an atomic reactor with a severely cracked shield building of still-dubious origin(s).

PII responded to this fourth NRC question:

> 4. Item 21: States that the lack of micro-cracks on the fracture surfaces eliminates a progressive aging failure mechanism or fatigue. However, in PII repot (sic, report); Exhibit 2; page 20 Figure 6b for cores A and D identified micro-cracks and Exhibit 2 Page 30 describes these cracks. Explain the presence/cause of these micro-cracks and why they are not considered or discussed in your conclusions in the RCR [Root Cause Report] on page 25?

PII responded by adding to Section 2.01 - Laboratory Tests and Examination to Test for Concrete Integrity (3rd paragraph) the following:

> The core-bores showed no signs of micro-cracking which, in combination with factors to be discussed in subsequent sections, eliminates a fatigue/progressive failure mechanism. The micro-cracks observed in the CTL report (Exhibit 2) are not representative of the areas observed by PII. The cores observed by PII were from locations exposed to repetitive loading and not the near-surface concrete observed by CTL.

This documented contradiction between CTL & PII regarding micro-cracking is quite significant. The near-surface concrete micro-cracking observed by CTL is almost certainly aging related, and should be addressed for risk significance in a hearing on the merits of this contention. This is especially so given the extensive nature of various types of cracking observed at numerous locations across the shield building. To that growing list must now be added near-surface concrete micro-cracking.

PII listed a fifth area of NRC inquiry:

> 5. Item 26: Provide and explain the input assumptions for the finite element analyses performed by your vendor (Exhibits 61 and 73) associated with the 1977 and 1978 blizzards events. Also, identify how sensitive your analysis conclusions were to each input assumption (*e.g.,* sensitivity study).

In response, PII added identical blocks of text to both (Appendix II, Section 2.05 - Exhibit 73 discussion; last bullet and Appendix II, Section 2.06 - Exhibit 61 discussion; last bullet). The block of text reads as follows:

> (ADDED TO Appendix II, Section 2.05 - Exhibit 73 discussion; last bullet):
> Assumptions: For the assumed depth of penetration of water (3-4"), PII performed a Rilem tube test and got a number very similar to our assumption (2-3"). For the strength we assumed 600-900 psi and tensile tests showed a range of 500-1000 psi. For the strain energy, we performed a calibration to a known crack. The elastic stiffness is validated by test data as well. Moreover, our conclusions are based on a reasonable set of input parameters that result in a plausible failure scenario. There is reasonable assumptions information, but we have determined that all other possible failure modes are not credible. Traditional sensitivity studies were not performed since this analysis is not a design basis analysis.

PII's admission that "Traditional sensitivity studies were not performed since this analysis is not a design basis analysis" is very significant. Intervenors assert that a 20-year license extension at a 40 year old atomic reactor with a very troubled safety record, as well as a severely cracked shield building, requires that robust engineering analysis be performed, including traditional sensitivity studies. A design basis-quality analysis should be required.

As revealed by a June 12, 2012 partial response by the NRC Staff to a Freedom of Information Act (FOIA) request made to the NRC by Intervenors on January 26, 2012, the NRC staff wrestled with FENOC's "operability/functionality" approach to returning Davis-Besse to full power operations, as opposed to a "design conformance" or "licensing basis" approach. *See* Memo, NRC's Hernandez to Sanchez-Santiago, 11/17/2011 (from NRC FOIA responses).

FENOC – which admitted in its February 2012 RCA that the shield building cracking has left the shield building "non-conforming to the current design and licensing bases" - has also wrestled with this challenge. Perhaps seeking its own "path of least resistance" (not unlike a propagating crack in the Davis-Besse shield building), the nuclear utility chose the approach that allowed immediate return to full power operations, while kicking the can down the road on "re-establishing" licensing basis design conformance. The NRC Staff did not object to this, even as it struggled to understand the legal and regulatory justification for such a move. In fact, the Staff generously granted FENOC a grace period until December 2012, during which time FENOC will attempt to complete a design basis conformance re-evaluation, in order to address significant licensing non-conformances created by the severe shield building cracking.

This nonconformance has much to do with age-related degradation of the shield building, further bolstering Intervenors' call for a hearing. Analogously to the findings of NRC's Office of

Inspector General in late 2002 regarding the hole-in-the-head fiasco at Davis-Besse, the NRC Staff seems once again to have put FENOC's profits ahead of public safety. Intervenors' main interest is to see that public safety is accorded a pre-eminent place in the 20-year license extension proposal at an atomic reactor with a severely cracked shield building.

PII listed a sixth NRC concern:

> 6. Item 27: Provide and explain the input assumptions for the finite element analysis performed by your vendor (Exhibit 62) associated with wind loading and the 1998 tornado event. Also, identify how sensitive your analysis conclusions were to each input assumption (*e.g.* sensitivity study).

In response, PII added to (Appendix II, Section 2.06 - Exhibit 62 discussion; last bullet) the following:

> Assumptions: The pressure loads due to the 105 mph wind were calculated in a separate_ REDACTION_ model and mapped to the Abaqus _REDACTION_ Model. The assumptions and modeling details are provided in Exhibit 67. Page 15, Figure 23 shows the surface pressure contours due to the 105 mph wind speed. Since the stresses are benign (< 1 psi) there is no need to perform a sensitivity study. Even a factor of 2 difference in any input parameter will not result in a significant stress change.

Given the multi-faceted degradation of the Davis-Besse shield building, however, all stresses should be very well understood. The grand total of such diverse stresses, after all, could add up to "failing" the shield building during a natural or man-made disaster, causing a catastrophic release of radioactivity to the environment. As above, NRC should require FENOC and its contractors like PII to undertake rigorous analysis, including sensitivity studies.

Additionally, Intervenors are concerned about redactions such as those above. Such redactions make it difficult for Intervenors to review and understand PII's and FENOC's analyses, or lack thereof, and their justifications for conclusions. We call on PII and FENOC to provide all information currently redacted in their revised root cause assessment and analysis, respectively.

A seventh significant area of NRC concern is described by PII (although it neglected to number this section):

> Item 46: PII states "The second most likely scenario is that during the blizzard, water intruded from the cracks in the dome of the structure and trapped in small gaps between the rebar and concrete. Upon freezing, the volume expansion of ice produced significant radial stresses that resulted in the observed cracking." Is this scenario also identified and explained in the FENOC RCR [Root Cause Report]? If so where? If not, why not? **Could a third environmental scenario (*e.g*. wind-driven rain & freezing conditions, moisture intrusion and loading) [have] existed after completion of the SB [Shield Building] wall, but prior to dome installation (May 1971-August 1975) [and] generated sufficient forces at inner rebar mat to cause laminar cracks?** Was this investigated? Explain.

(Emphasis added).

In response, PII added to its main report, Section 2.05 - top of page 7, the following:

> …penetration and below freezing temperatures, the outer layers of the Shield Building expanded due to crystallization of the diffused moisture trapped in the concrete. The volume expansion in the outer layer of the concrete, especially in the thick shoulder areas, produced significant radial stresses, which initiated and propagated the laminar cracking in the outer rebar mat. This theory could not be confirmed by direct testing since the limited number of strength tests precluded the possibility of making a statistically significant analysis of such damage. A very large number of tests throughout the structure would have been required and there is no guarantee that the tests would be sensitive enough to identify such variation. The variation in the tests performed points to this problem.

Quite significantly, this question by the NRC Staff, conveyed in PII's listing of revisions, represents the first time that the public has been told about an entirely different source of cracking potential in the shield building:

> "The second most likely scenario is that during the blizzard, water intruded from the cracks in the dome of the structure and trapped in small gaps between the rebar and concrete. Upon freezing, the volume expansion of ice produced significant radial stresses that resulted in the observed cracking." Is this scenario also identified and explained in the FENOC RCR [Root Cause Report]? If so where? If not, why not?

NRC had to ask PII and FENOC why this second most likely scenario for shield building cracking during the Blizzard of 1978 was not even mentioned in FENOC's Feb. 28, 2012 RCA.

Tellingly, PII's revised response does not even answer that question.

Intervenors join the NRC Staff in demanding to know why such a significant potential source of cracking – water infiltration via pre-existent cracks in the dome of the shield building – was not even mentioned in the FENOC RCA on Feb. 28, 2012? FENOC finally did mention shield building dome cracks in its May 16, 2012 revised root cause analysis report ("RRCA"). These cracks were documented as early as 1976 – long before the Blizzard of 1978. Intervenors have noted the significance of admitted 1976 dome cracking in previous supplements to their contention.

Intervenors find PII's -- and by implication FENOC's – disinterest in rigorous and robust testing and analysis highly troubling. PII admits its "theory could not be confirmed by direct testing since the limited number of strength tests precluded the possibility of making a statistically significant analysis of such damage. A very large number of tests throughout the structure would have been required and there is no guarantee that the tests would be sensitive enough to identify such variation. The variation in the tests performed points to this problem."

Essentially, PII is arguing that because the tests would be challenging and expensive, PII -- and by extension FENOC -- simply choose not do them, and simply assume their theory is correct. Thus, PII's root cause assessment and FENOC's root cause analysis are no more than mere educated guess work, at best, un-tested, un-substantiated with empirical data. Apparently, in order to save money, time, and bother – or, perhaps to avoid revealing inconvenient truths -- PII and FENOC have chosen to not do rigorous, robust, and comprehensive testing. To make matters worse, NRC has let them get away with it. Intervenors urge that NRC require FENOC and PII to confirm their theory by direct testing, including a statistically significant quality and quantity of strength tests throughout the shield building structure. To guarantee that "the tests would be sensitive enough to identify such

variation," NRC should require FENOC and PII to undertake high quality, robust sensitivity studies. Given the potentially catastrophic risks of shield building failure, such rigor is necessary, and should be required as part of this license extension proceeding.

NRC staff asked PII another question which was apparently simply not answered in its revised root cause assessment report:

> Could a third environmental scenario (e.g. wind-driven rain & freezing conditions, moisture intrusion and loading) [have] existed after completion of the SB [Shield Building] wall, but prior to dome installation (May 1971-August 1975) [and] generated sufficient forces at inner rebar mat to cause laminar cracks? Was this investigated? Explain.

Intervenors asked much the same question in previous supplements to their contention, once FENOC's RRCA (dated May 16, 2012) had revealed to them that the shield building had remained uncapped, exposing its interior to the elements, for several years before its dome was installed.

PII then went on "This mechanism was explained in Section 6.02 Failure Mode 2.7 on page 15." (Actually, it was on page 17, not page 15. Additionally, this section appears to be duplicative of #9, Item 48, below.) Following is the text PII added:

> Section 6.02
> Failure Mode [FM] 2.7 [Concrete Sealant]
> a. Discussion
>
> There are two types of moisture transport processes in the Davis Besse Shield Building that provide sufficient moisture to be entrapped in the concrete. One may be called "Top-down moisture penetration", and the other may be called "External-internal moisture penetration". The top-down penetration results in high moisture content near rebar regions and what we call the sub-mode I laminar cracking, as will be described in FM 3.6. The external-internal transport causes high moisture content in the outer layer of concrete, which leads to what we call the sub-mode 2 delamination cracking which will be described in FM 3.6 as well. The following section describes the two types of moisture transport processes in Davis-Besse Shield Building.
>
> A Third theory involved freezing of water that penetrated into roof/parapet joint, causing radial stresses. However, the two potential mechanisms identified preclude cracking on the inside since it is not exposed to the same deep freezing conditions as the outside. Three 'full-depth' cores showed no indication of cracking on the inside of the wall, and the

> construction opening that originally identified the laminar cracking showed no crack at the IF [Inner Face] rebar. Cracking was only found at the OF [Outer Face] rebar.

As NRC's own question highlighted, the Inner Face of the shield building wall was exposed to freezing for a number of years, prior to installation of the dome cover, as well as prior to closure of the initial construction opening.

At Page 18 [38 of 257], PII states:

> The top-down moisture penetration
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> The top-down moisture transport process assumes that the water comes from the top of the structure and slowly penetrates down within the concrete wall. During the construction of the Shield Building, the wall was built first and the dome was subsequently constructed two years and four months later. So, the jacking bars, dense rebar, and top of the concrete wall were all exposed to the environment. Moreover, initial defects may be generated by the jacking bars and dense rebar, together with the large aggregate used in the concrete. These factors resulted in the potential for high porosity concrete near the rebar and jacking bars allowing for water penetration. Due to the heterogeneous characteristics of concrete, the water comes down along random paths of least resistance which may tend to explain the sporadically distributed cracks in the wall. This moisture transport mechanism is illustrated in Figure 4.[3] (emphasis added)

Oddly, these revelations appearing in PII's revised root cause assessment report appear to have been omitted from FENOC's May 16, 2012 RRCA, which, just like the February 28, 2012 Root Cause Report, focused almost entirely on the Blizzard of 1978 explanation for sub-surface laminar cracking in the shield building exterior side walls. A keyword search for "top-down" and "roof" in the May 16, 2012 FENOC revised root cause analysis report revealed no hits for the former, and no relevant hits for the latter. Despite NRC's question, and PII's acknowledgement of the question, neither PII nor FENOC have given adequate, or any, attention to this additional potential root cause for shield building cracking.

In addition, PII's admission that "the wall was built first and the dome was subsequently

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[3] Fig. 4 is not on Page 16, as PII indicates, but rather on p. 19.

constructed two years and four months later. So, the jacking bars, dense rebar, and top of the concrete wall were all exposed to the environment" bolsters Intervenors' arguments along these lines introduced in previous contention supplements, pointing out the vulnerability of the shield building's interior to moisture exposure through the incomplete open dome from above, as well as through the side wall initial construction opening (and two "temporary" side wall openings, in 2002 and 2011, to swap out reactor lids).

PII's confession that "Moreover, initial defects may be generated by the jacking bars and dense rebar, together with the large aggregate used in the concrete. These factors resulted in the potential for high porosity concrete near the rebar and jacking bars allowing for water penetration," when taken into account along with such pre-operations defects as "out of plumb" construction of the shield building, cracking on the shield building dome, *etc*., begs the question: could not the various cracking and other degradation at diverse locations on the shield building be attributable to not only the Blizzard of 1978's wind-driven precipitation into the exterior side walls, but also to a top-down dynamic, if not other causes to boot? Without a comprehensive root cause analysis, PII and FENOC cannot guarantee that age-related degradation of the shield building is comprehended, and that appropriate protections are in place to defend against it.

Intervenors also challenge the acceptability of FENOC performing only three full depth core bores. Three core bores across the entire surface of the huge shield building is not acceptable, is much too small a sample size. It provides a mere snap shot, frozen in time, of mere cubic inches (and mere square inches of surface concrete), versus the thousands or tens of thousands or hundreds of thousands of cubic feet of shield building structures, which very well may be suffering worsening cracking over time.

PII lists an eighth set of NRC questions:

> 8. Item 47: PII states: "Shield Building expanded due to crystallization of the diffused, moisture trapped in the concrete." And on Pg 24 "when an excessive amount of ice forms in pores, the ice generates cracks in concrete." What concrete tests were performed to confirm this assumption that freezing and crystallization of ice in pores causes internal cracking damage the SB concrete? If no tests were done explain. Were SB concrete tensile and compressive properties tested in the areas assumed affected by ice crystallization? Explain.

In response, PII added to the main report, Section 2.05 - top of page 7, the following:

> …penetration and below freezing temperatures, the outer layers of the Shield Building expanded due to crystallization of the diffused moisture trapped in the concrete. The volume expansion in the outer layer of the concrete, especially in the thick shoulder areas, produced significant radial stresses, which initiated and propagated the laminar cracking in the outer rebar mat. This theory could not be confirmed by direct testing since the limited number of strength tests precluded the possibility of making a statistically significant analysis of such damage. A very large number of tests throughout the structure would have been required and there is no guarantee that the tests would be sensitive enough to identify such variation. The variation in the tests performed points to this problem.

Intervenors repeat their criticism of PII's and FENOC's lack of rigorous and robust, data-based analysis articulated above at PII's seventh point, addressing NRC's "Item 46." PII and FENOC provide convenient excuses for not performing rigorous tests, and performing robust analyses based on empirical data, an approach which flies in the face of the potential risks of Davis-Besse operating from 2017 to 2037 with a severely cracked shield building.

PII acknowledges a ninth area of very significant NRC inquiry:

> 9. Item 48: PII report shows picture of standing water between roof dome and parapet and picture stating "freeze-thaw damage in the roof concrete." It appears this condition would allow water to intrude/collect in the parapet to roof joint and if followed by freezing conditions, ice would expand within this joint. What effect would this have on the stress applied to the SB structures? Was this condition analyzed by FE [Finite Element] techniques? If not, why not? **It appears if ice forms within this joint it would create radial stress on the parapet and top of SB [shield building] wall, at roof (and tensile loads on inside SB wall near roof).** Were any examinations (other than visual) performed on the roof or parapet? If not, why not. **Were any type of examinations conducted at the inside surface of the SB wall just below the parapet to identify cracking?** If not, why not? What

actions proposed preclude this scenario from causing further cracking (*e.g.* is top surface sealing identified)?

(Emphasis added). Rather than adequately answer these questions, PII again provides only the response it previously supplied in answer to "Item 46" (NRC's seventh point) above, which Intervenors reproduce in the margin.[4]

And, as with Item 46 above, PII briefly described a "Top-Down Moisture Transport Mechanism," including its Figure 4.

These are not adequate answers to NRC's important questions. NRC's questions have called attention to a neglected potential cause of significant shield building damage over the past years and decades with portents for the future, *i.e.*, the proposed 20-year license extension.

PII has acknowledged in response to NRC questioning that the dome and parapet standing iniwater caused "freeze-thaw damage in the roof concrete." That information may provide the missing explanation for why FENOC's predecessor nuclear utilities, including Toledo Edison, weather-sealed the dome, because of documented cracking damage as early as 1976, pre-operations.

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[4]a. PII: (ADDED TO main report, Section 6.02 - bottom of page 17)
Section 6.02 Failure Mode [FM] 2.7 [Concrete Sealant]
a. Discussion

There are two types of moisture transport processes in the Davis Besse Shield Building that provide sufficient moisture to be entrapped in the concrete. One may be called "Top-down moisture penetration", and the other may be called "External-internal moisture penetration". The top-down penetration results in high moisture content near rebar regions and what we call the sub-mode I laminar cracking, as will be described in FM 3.6. The external-internal transport causes high moisture content in the outer layer of concrete, which leads to what we call the sub- mode 2 delamination cracking which will be described in FM 3.6 as well. The following section describes the two types of moisture transport processes in Davis-Besse Shield Building.

A Third theory involved freezing of water that penetrated into roof/parapet joint, causing radial stresses. However, the two potential mechanisms identified preclude cracking on the inside since it is not exposed to the same deep freezing conditions as the outside. Three 'full-depth' cores showed no indication of cracking on the inside of the wall, and the construction opening that originally identified the laminar cracking showed no crack at the IF rebar. Cracking was only found at the OF rebar.

In fact, FENOC's RRCA of May 16, 2012 acknowledges that the dome sealing had to be re-done, as it was applied too thickly (1/4 inch thick) and was peeling off. Before the issuance of the RRCA, Intervenors, as well as the public and the news media had not known about the dome cracks, documented 36 years earlier.

PII and FENOC have not answered NRC's specific questions, not even in FENOC's RRCA. Given the catastrophic risks of shield building failure during a 20-year license extension at Davis-Besse, Intervenors seek answers to these and many other questions at an adjudication on the merits.

A tenth area of NRC inquiry is listed by PII:

> 10. Item 49: Why does this section of the report discuss 2-3 inch penetration for wind driven rain, but other tests used in your FE [Finite Element] analysis were based on work at UC Boulder that show 3-4 inch penetration with 90 mph winds?

PII responded by adding to the *main report, Section 6.02 - top of page 21,* the following:

> …region L[v]. The sum of the two depths is called L[m], (L[m] = L[w] + L[v]), representing the depth of concrete with high moisture content.
>
> Exhibit 72 shows that the water penetration depth depends on permeability of concrete and it can vary in a very large range. For solid concrete without distress, the 1D analytical results showed that the penetration depth could be 2 - 3 inches under a strong wind-driven rain. With surface distress such as microcracks and 2D moisture penetration, the depth of high moisture region could be higher. Moreover, the moisture trapped in the concrete could continue to penetrate into the concrete after the blizzard, resulting in a higher depth of the high moisture region.
>
> Therefore, in the 1978 models, the depth of moisture penetration is considered approximately 3 to 4 inches in locations subjected to 1D moisture diffusion.
>
> As a summary, based on preliminary and approximate analyses for solid concrete without major distress, the depth of high moisture region L[m] is about 2 to 3 inches after a few days of WDR [wind driven rain]. This may be considered as a reference or guideline for determining the depth of high moisture region in the concrete wall. The present results are based on 1-D analysis. The concrete in shoulder areas is subjected to 2-D moisture penetration, and thus the high moisture region L[m] in shoulder areas may be higher than that in the wall between shoulders.

NRC's questioning on this set of issues is significant. There are only 3 inches of concrete cover over the outer rebar mat. FENOC has acknowledged areas of the shield building where degradation, construction errors, etc. have resulted in even less concrete cover over the outer rebar mat. A 3-4 inch penetration could thus lead to rebar exposure to moisture, which could corrode rebar, leading to crack initiation or propagation. Four (4) inches of moisture penetration could also do more structural damage to concrete than 2 inches of moisture penetration.

PII admits that its analyses are "preliminary and approximate." Yet, there appear to be no comprehensive and conclusive analyses planned in follow up. FENOC not only restarted the Davis-Besse reactor on December 6, 2011, with NRC's blessing, but claims that weather sealing the shield building will prevent any worsening of the extensive cracking. Intervenors are not only skeptical of PII's and FENOC's optimistic claims, but very concerned that more rigorous tests and analyses will not be required by NRC before it grants Davis-Besse a 20 year license extension.

PII lists NRC's eleventh area of inquiry:

> 11. Item 50 (Exhibit 61): PII judged the 1977 blizzard to be the "second worst" in terms of environmental factors which can cause laminar cracking: Could this laminar cracking have been caused by the 1977 blizzard since according to Exhibit 61 of the PII repo[r]t stresses during this blizzard approached the tensile strength of the concrete and may exceed this level when modeling accuracy is considered? Also; identify the expected FE [Finite Element] model accuracy for this application and how it was1 *(sic)* determined (e.g. benchmarked)?

In response, PII added to the main report, Section 2.04 - middle of page 6, the following:

> Out of the top 3 blizzards to which the Davis-Besse Shield Building has been subjected, the root cause investigation found that the most likely triggering event is The Toledo Blizzard of 1978. Only this scenario had the existing combination of wind, moisture and temperature extremes to generate the significant stresses required to produce the observed laminar cracking. To confirm, the second worst blizzard, occurring in 1977, was also analyzed using finite element thermal and stress analysis. The results show that the radial stresses do not exceed the tensile capacity of the concrete and therefore most likely could not have contributed to the observed crack. The 1977 Blizzard stress analysis suggests

> that the peak max principal stress approached the tensile strength. However, the area of high stress is limited to a very small area (See Figures 14 - 17). The stress contours during the 1978 Blizzard (shown in Figures 7 - 13) show a significantly larger area subjected to high stresses. The difference in the stress results during the two Blizzards is significant and larger than the expected uncertainty in modeling. **This is based on engineering judgement. There was no sensitivity analysis performed. (emphasis added)**

So PII admits that its analyses are not rigorous and robust: conclusions are based on "engineering judgment," not empirical data; and, "there was no sensitivity analysis performed." Therefore, PII's revised root cause assessment report is based on a weak scientific/technical/engineering basis. Where is the proof of their theories, apart from educated guesswork/conjecture? It could well be that PII has not identified actual root causes of shield building cracking, as no solid grounds for confidence in their hypotheses are provided.

NRC's questions point out compellingly that there is not a single root cause to shield building cracking, but potentially multiple root causes. Despite this, PII and FENOC cling to their ultimate root cause theory, that the Blizzard of 1978 was the only explanation for shield building cracking. But given the presence of multiple kinds of cracking, located at diverse places across the huge shield building, NRC's questions raise the specter that PII and FENOC have not adequately explained the origin of all cracking. This would leave the shield building vulnerable to yet unidentified cracking initiation and propagation dynamics.

A hearing on the merits must be convened to shed light on these many unanswered questions.

PII lists NRC's twelfth area of questioning as follows:

> 12. Item 51: The equation for cracking parameter Sc uses a concrete tensile strength of 973 psi. This is not consistent with root cause and other PII report sections that indicate 600 psi is a more representative number. Why was this number used and what impact does it have on the analysis and conclusions?

PII responded by adding the following note to Appendix III - near center of page III-I:

> Note: The measured F[t] value of 973 psi was replaced with 'effective strength' of 600 psi for the cracking models since experience shows that it is necessary to use a lower "effective" strength in the cracking models for multiple reasons.

PII and FENOC may have used non-conservative figures/values for shield building strength, and accordingly, Intervenors urge NRC not to allow such a practice in its license extension regulatory reviews. A hearing on the merits, with the opportunity to cross-examine FENOC's consultants and experts, would shed important light on such devils in the details.

The significance of such issues is revealed in documents provided to Intervenors by NRC in response to a request submitted pursuant to the Freedom of Information Act (FOIA; Intervenors' request submitted January 26, 2012; NRC's partial response provided June 12, 2012; Case # 2012-0121). Take, for example, FOIA response document "B/9," dated 11/04/2011 and described as "Email from P. Hernandez, NRR to E. Sanchez-Santiago, RIII on Questions about Davis Besse Shield Building Report from DORL."[5] In it, Pete Hernandez, assistant to the Lead PM [Project Manager] for Davis-Besse Mike Mahoney [as revealed in document B/8], responds to "C-CSS-099.20.054," a "calculation [of] the structural integrity of the SB [shield building]…considering the presence of an interfacial/circumferential crack between the SB structural concrete shell (*i.e.*, the 30'' thick reinforced concrete SB) and each architectural flute shoulder (16 flute shoulders in total), as described in Attachment B." He states:

> "This description makes me think that they are looking at a single crack going in a circle. From what I understood **the crack is pervasive along the entire surface, spidering in all directions, similar to a pane of tempered glass breaking.** The description in Attachment B addresses only the crack at the opening and assumes that the crack is right along the rebar line. **The core bores have shown that the cracks are at different depths so this doesn't seem to capture the current situation.** Throughout the calculation, the word

[5]Intervenors have attached a copy of this email to this motion.

> Crack, singular, is used. They also mention that the extent of the crack is only 10'-12'**. This seems to greatly downplay the issue."**

(Emphasis added). Mr. Hernandez continues:

> "At this point core bores of only the shoulders have been taken. So the only crack widths we are aware of are those in the shoulders, which are not being addressed. How can an analysis be done on the structurally credited concrete if no data from that area, in the form of core bores, has been taken? Shouldn't the structural integrity of the shoulders be calculated as well?"
>
> "This seems to say that they are just doing calculations for the new concrete that is and ignores the rest of the building altogether. Is that right?"
>
> "This says to me, that they are ignoring the shoulders, if they are ignoring all that concrete, it seems to be the opposite of conservative for evaluating the mechanical loads."

Regarding C-CSS-099.20.055, the "Objective or Purpose" is stated as: "The purpose of this calculation is to demonstrate that during a seismic event, with the development of the crack in the architectural flute shoulder, the capacity of the rebar(s) can still provide adequate anchorage thus prevent **cracked concrete piece from falling**, and therefore Seismic II/I condition can be maintained." (Emphasis added).

The NRC's Hernandez responds to this explanation as follows:

> "**I think the greater concern is will the SB stay standing** and not whether or not the decorative concrete will fall off. Because the licensee has not performed core bores to see if there is cracking in the credited concrete, **do they have a basis to say that the structural concrete will maintain a Seismic II/I condition?"**
>
> "This use of singular terminology also discounts this calculation because it seems that they are looking at only 1 crack and 1 shoulder or 1 flute. **Because cracks have been found through multiple core bores, shouldn't the appropriate calculations account for the combined effects of cracks in all the shoulders** and not just one by opening and not just individually?"
>
> "From what I understand, **IR mapping is only an indicator, but must be validated by core bores**. Does basing all the calculations on a length of a 12 foot crack discount the calculations altogether, because **we have indications of cracks at distances greater than 12 feet.** This also seems to assume that there is only 1 crack and not *many as the core bores seem to prove*. Isn't **IR mapping only useful at a limited depth too**, so that using it to evaluate a 48" thick piece of concrete is not realistic? (Emphasis added).

Intervenors are concerned about the safety implications raised by Mr. Hernandez' questions. He goes so far as to speculate whether the shield building will "stay standing" if an earthquake occurs. He questions whether or not FENOC and its contractors have proven that "structural concrete will maintain a Seismic II/I condition" - earthquake concerns which are shared by Intervenors. Mr. Hernandez acknowledges limitations on Impulse Response tests, and calls for core bores to be taken across the shield building. Intervenors also call for adequate core bores to take place, to identify any and all cracking at whatever depth may be occurring. FENOC's and PII's limited IR and core bore sampling could be missing significant areas and depths of cracking.

Mr. Hernandez' concerns are echoed by NRC staff person Abdul Sheikh. In FOIA response document B/26 [dated 11/22/11, described as "Email from A. Sheikh, NRR to E. Sanchez Santiago, RIII on Questions for the Conference Call],[6] Mr. Sheikh states:

> **"If this assumption is correct only 3-4 inches of the concrete on the inside face can be used in the structural analysis.** In the response to the questions, the applicant stated that, 'Since we assume that outside reinforcement is to be treated ineffective in carrying any additional stress beyond 12.4 ksi, under accident thermal loads that may cause stresses in excess of what the rebar can carry (assumed 12.4 ksi), **the reinforcement is assumed to detach itself from the outer section of the shell.' These statements seems *(sic)* to be contradictory. In addition, I am concerned that the concrete will fail in this region due to bending in this region even under small loads."** (emphasis added)

Thus, Mr. Sheikh not only indicates he's concerned a "small load" will fail the concrete of the shield building, but he quotes FENOC itself, which admits:

> 'Since we assume that outside reinforcement is to be treated ineffective in carrying any additional stress beyond 12.4 ksi, under accident thermal loads that may cause stresses in excess of what the rebar can carry (assumed 12.4 ksi), **the reinforcement is assumed to detach itself from the outer section of the shell.'** (emphasis added)

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[6]Intervenors have attached a copy of the cited email to this Motion.

Additionally, Mr. Sheikh goes on to issue a number of related warnings (numbered this way in his email):

1. Mr. Sheikh notes internal contradictions in FENOC/contractors' documents regarding the rebar lap splice issue (which FENOC's own expert witness, Dr. Darwin, has pointed out is very significant – he has indicated that his support for FENOC's root cause conclusions hinges on cracking not being in the lap splice region).

2. Mr. Sheikh states: "If this is the assumption, stress used for lap splice calculation should account for 100% increase in the stress."

Mr. Sheikh further states:

5. "The licensee justification for ignoring the dead (DL) and normal thermal (To) in calculation of rebars splice does not appear to be justified. The stresses due to dead load and thermal loads will be locked in the rebars and cannot be ignored."

6. "The licensee considers the allowable stress in the rebar to be 60 ksi and ignores a phi factor (0.9) in his evaluation for lap splice. In addition, the licensee has not accounted for any additional uncertainty due the conditions."

7. "I am not aware of any pull tests carried out with a crack in the plane of the rebar. Can the licensee provide any documentation for this statement."

8. "The licensee is using numerous assumptions in his summary report and calculations that are not described in the UFSAR and ACI 318-63, and still calls it a design basis calculation. Can the licensee provide justification for this approach."

In a thirteenth area, PII recites NRC's questions and concerns as follows:

13. Item 52: FM [Failure Mode] 2:12 discusses Out of Plumb condition of SB [Shield Building] walls (original construction field report No.5), but did not investigate effect of this condition on the friction forces at the slip forms: Specifically, the out of level condition can create higher friction forces on slip forms which can cause internal laminar tears/cracking the uncured concrete at the reinforcement steel. Identify and provide the tests/analysis performed to rule out this potential cause as the initiation site for the laminar cracking observed. If no investigation of this potential cause was performed identify planned corrective actions. Reference "Slip forming of Vertical, Concrete Structures Friction between concrete and slip form panel" by Kjell Tore Fossa - Dr. Thesis- Section Below from Chapter 2, pg 33 of this document:

"Delamination of the concrete in the cover zone is concrete separated or displaced from the substrate: **A vertical crack in the cover zone parallel to the reinforcement and sometimes invisible on the surface, is delamination of concrete.** Delamination is also areas where the concrete in the cover zone is lifted together with the panel and makes the cover deficiency on the wall face clearly visible.

Delamination is often related to:

- Problems during start up,

- Geometry changes,
- Area above embedment plates and block outs
- **the slip form is not in level"**

(emphasis added).

PII responded that this issue is "Discussed in Appendix VI, FM 2.12 – Discussion," as follows:

> Discussion:
>
> Documentation of the Out of Plumb condition was limited to the documents provided. We do not have information regarding the method of correcting the problem and whether it caused excessive friction forces.
>
> Attempts to correlate these locations to locations of cracking found no significant correlation. The out-of-plumb condition peaked at three distinct (Exhibit 18) elevations that did not correspond to cracking as determined by CTL.
>
> Exhibit 5 (Project specifications) provides information regarding design considerations that reduce friction.
>
> The rate of slip-forming (average about 4' per shift) is fast enough to minimize friction problems.
>
> The observed cracking through aggregates is further indication that the laminar cracking happened after the concrete reached sufficient maturity and not during placement.
>
> Conclusion:
>
> The out-of-plumb issues did not cause the Laminar Cracks

PII admits, "We do not have information regarding the method of correcting the problem and whether it caused excessive friction forces." Thus, out of plumb construction errors – which may have never been rectified at all -- must be added to the growing list of stresses borne by the Davis-Besse shield building (which, during construction alone, included the following):

> "Noteworthy deviations during construction of the shield building walls were issues such as concrete with the wrong water to cement ratio, concrete with smaller coarse aggregate size, concrete with the wrong type of cement, exceeding shield building wall tolerance for plumb, installation of reinforcing steel, embeds, or reglets, and omission of blockouts. The shield building construction deviations are described in attachment 8."

FENOC RRCA, May 16, 2012, p. 45/131 of .pdf). What is known, however, as admitted by FENOC in its RRCA (p. 100/131 of .pdf), comes from "Interim Field Report #5":

> The shield building concrete wall outside face is not within the plumb tolerance of 1 inch in any 25 feet. Reference Specification C-38.
>
> Bechtel Engineering has reviewed the Interim Field Report and its attached plumb plots. Out of tolerance exceeds the 1 inch in 25 feet specified by 2-3/4 inches. The affect this has on the shield building structural integrity were found to be insignificant. Bechtel Engineering approves the Use As Is disposition for the structure and recommends that all interface work be adjusted to meet the as-built alignment of the structure.

Thus, Bechtel during Davis-Besse shield building construction largely chose to ignore out-of-plumb stresses. Bechtel neither recorded any method of correcting the problem, nor whether it caused excessive friction forces. It simply proceeded to build the Davis-Besse shield building as if the out-of-plumb errors had not occurred.

It is also unclear how carefully even CTL, FENOC's contractor, checked for shield building damage due to out of plumb slip form friction forces. Not finding problems when one is not carefully checking for them is to be expected. Predictably, PII – as does FENOC itself -- continue to focus exclusively on sub-surface laminar cracking, without addressing other, yet still significant, degradation of the shield building structure due to additional forces, such as out of plumb construction flaws.

PII lists a 14th area of NRC questioning:

> 14. Item 54: PII modeling suggests that SB laminar cracking initiated by debonding at the interface of concrete / rebar along the outer reinforcement; however core bore laminar crack depths exist away from the rebar mat depth. How is this possible explain *(sic)*?

PII responded by adding the following note to Analysis I, section 9.01 - page 33 before table 3:

> Note that the models' suggestion that SB laminar cracking initiated by debonding at the interface of concrete/rebar along the outer reinforcement may appear to conflict with the observation that some core bore laminar crack depths exist away from the rebar mat.
>
> However, in concrete, cracks that initiate at the concrete/rebar interface may 'wander' through the 'path of least resistance' as it propagates. Variation in localized material strength

> could readily cause such crack 'wandering'. It is likely that these cores encountered such condition.

The NRC question challenges the PII, and ultimately FENOC, root cause conclusions, even in revised form. Empirical evidence shows cracking deeper than the PII/FENOC revised root cause models admit to/explain. Thus, the explanations could very well be off base. The potentially catastrophic consequences of a shield building failure do not allow for the luxury of not addressing the still unexplained observation that cracking extends significantly more deeply than PII's/FENOC's "Blizzard of 1978" theory accounts for.

That "cracks … may 'wander'" through the "paths of least resistance" is not a rigorous, robust analysis based on empirical evidence. Where is the supporting data, other than guesswork or so-called "expert judgment"? PII has denied the presence of significant micro-cracks (but not all micro-cracking) in shield building wall structures, which would suggest age-related degradation. But this admission by PII of "observation that some core bore laminar crack depths exist away from the rebar mat" seem to indicate cracks – in other words, ***macro***-cracks. This could indicate that initial micro-cracks grew/have grown significantly over time - an age-related degradation phenomenon. Neither PII nor FENOC have adequately addressed the as yet unexplained presence of subsurface laminar cracking at a deeper depth in the shield building wall beyond the outer rebar mat.

PII then lists a fifteenth area of NRC questioning:

> 15. Item 55: PII model suggests crack propagation by freezing the void fraction available in the concrete. What modeling was done to evaluate crack propagation which did not occur by freezing (*e.g.*: laminar cracking identified in the MS [Main Steam Line] room near areas that have been confirmed to remain above 100F during operation)? If no modeling can explain this crack propagation identify why this crack exists.

At Page iii. PII responds by adding the following note to Analysis I, section 9.01 - page 32 before table 2:

> The "motivating force" is the void fraction of elements treated as ice, *e.g.* 0.6% and 1% of the _half line of redaction_ The "rebar spacing" variable is summarized above and presented in the legend, and the "extent of cracking" is a scale from 0 to 3 that serves to simplify the extent of the damage observed in each model. The meaning of each level from 0 to 3 is described in the third legend following the table below. A level of "3" is a complete delamination along the OF [Outer Face] rebar mat similar to the center of shoulder 9 at the top of the shield building. A level of "0" is no damage.

What the results show is that there is a clear trend toward more damage with tighter rebar spacing. The models with all 12" rebar spacing showed no laminar cracks at all. Accordingly, the laminar cracking identified in the MS [Main Steam Line] room near areas that have been confirmed to remain above 100F during operation can be explained by a weakened plane in the concrete, created by the presence of very high density rebars in the OF rebar mat plane. This plane allows a crack to propagate with relatively little motivating force.

Thus PII has further admitted that dense spacing of rebar has inevitably led to a significant design flaw that compromises shield building integrity. But PII has not clearly communicated empirical calculations showing the safety significance of this admission – such as quantifying the "small stress," as Mr. Abdul Sheikh worded it above – that would be enough to "fail" these areas of the shield building, risking a radiological catastrophe during core meltdown conditions. Such extensive cracking in areas of dense rebar in the shield building structure certainly violates Davis-Besse's licensing design basis conformance.

And PII's redacted half line, noted above, complicates Intervenors' ability to fully understand PII's response to NRC's question. PII must provide full, transparent explanations, filling in the redaction blanks. No explanation whatsoever is given for the redactions, leaving Intervenors in the dark.

PII's revised root cause assessment report lists this sixteenth NRC question:

> 16. Item 56: Why was the thermal conductivity of the SB [Shield Building] concrete 50% higher than the highest range expected for concrete? Did this contribute to an increased depth of freezing such that the area susceptible to cracking was at the outer rebar mats?

PII responded as follows, added to Analysis I, section 10.02 - page 39 end of 3rd paragraph:

> …The thermal properties of concrete reported in Exhibit 59 depend on many parameters such as moisture content of concrete and type of aggregate. The important thermal parameter is the thermal diffusivity which includes the effects of both conductivity and specific heat.
>
> Tests of moisture penetration were also performed at the University of Colorado at Boulder, which showed that a _REDACTION_ water penetration up to 3 or 4 inches is possible when there are winds in excess of 90 mph (such as during the 1978 blizzard)…

Once again, the above redaction is not even explained – no justification for the redaction is provided, leaving Intervenors doubly in the dark. But this redaction pales in comparison to a section above the quoted text: above the quoted text, more than half of the page is redacted without explanation! This violates basic democratic norms of transparency and accountability. Intervenors speculate whether the redactions represent efforts to protect legitimate business secrets, or are aimed at thwarting public access to embarrassing truths about the shabby state of the shield building. Given the shield building's fundamental role in protecting human health, safety, and the environment from radiological catastrophe, such extensive redactions are not acceptable. Intervenors call for full disclosure, in the public interest.

If Davis-Besse's shield building concrete conducts heat 50% faster than it is supposed to, this may have allowed or caused deeper cracking in the shield building. Did Davis-Besse use substandard concrete in the shield building construction? Is this another design and/or construction error in the Davis-Besse shield building? Is this also a non-conformance to licensing and design bases? Why, when FENOC has blamed the Blizzard of 1978 and lack of a weather sealant on the shield building

exterior as root causes of the subsurface laminar cracking in the shield building wall, didn't the utility also mention this concrete thermal conductivity issue? What other negative properties does the substandard Davis-Besse shield building concrete have? What other natural or man-made assaults is it therefore vulnerable to? A hearing on the merits of Intervenors' cracked concrete containment contention, as supplemented, might illuminate answers to these important questions.

PII lists a seventeenth NRC question, related to the one just discussed:

> 17. Item 57: It does not appear that the FE [Finite Element] stress analysis of the SB incorporated the abnormally high thermal conductivity measured for the SB (exhibit 59). Instead, only the measured coefficient of thermal expansion was included in the FE analysis. Why didn't the FE analysis account for the uniquely high thermal conductivity measured for the SB concrete? What effect would it have on the analysis to account for this parameter?

PII responded by adding the following note to Analysis III, section11.02-page 52 3rd paragraph:

> The thermal conductivity and specific heat of DB concrete were used as inputs for the FE thermal analysis. The thermal diffusivity was calculated by the FE program based on the input values for thermal conductivity and specific heat. In the linear thermal analysis for temperature distributions in the concrete structure, the important thermal parameter is the thermal diffusivity which is in the typical range for concrete, as shown in Exhibit 59. One can see from Exhibit 59 that both thermal conductivity and specific heat of DB concrete have abnormally higher values than the typical values shown in the literature. Thermal diffusivity =Thermal-conductivity/ (specific heat x density).

Once again, redactions preceding this text complicates the task of trying to understand PII's, and by extension FENOC's, root cause assessments and analyses. Full disclosure is obligatory.

PII admits that the Davis-Besse shield building concrete "thermal conductivity and specific heat…have abnormally higher values than the typical values shown in the literature." NRC already asked the significant question, did this contribute to the shield building sidewall subsurface laminar cracking, as by allowing deep freezing down to the outer rebar mat layer? Neither PII nor FENOC have answered that question adequately, if at all. Even the revised root cause assessment and analysis

did not mention any significant root cause role for substandard concrete. But substandard concrete's "abnormally high" thermal conductivity and specific heat cannot be solved by the mere application of a weather sealant to the Davis-Besse exterior shield building wall 40 years late. What other vulnerabilities would such substandard concrete expose the Davis-Besse shield building to? A full hearing on the merits would shed light on these important questions.

NRC's specific questioning on the quality and strength of Davis-Besse's shield building concrete continued into an eighteenth area:

> 18. Item 58: How was the tensile strength of the SB concrete range of (836 to 962) used in this analysis determined? Why was the tensile strength representative of the concrete properties in *1977* and 1978? Explain?

PII responded by adding the following note to Section 2.01 Laboratory Tests and Examination to Test for Concrete Integrity-page 2:

> Section 2.01 Laboratory Tests and Examination to Test for Concrete Integrity
> PII performed extensive analyses of fracture-surface characterization and measurements of concrete material properties. Laboratory tests performed on concrete cores extracted from the Shield Building show that the concrete has both high compressive and tensile strength characteristics. Strength increase in concrete is larger at early ages and stabilizes after a few years; on the other hand, the strengths of concrete can decrease over time due to aging related mechanisms such as freeze-thaw cycles and chemical attacks. There was no available data to determine the strength development rate for the SB wall concrete.

PII responded above, not with specific empirical data, but rather only with qualitative arguments. As documented at the fifth area of NRC questioning (Item 26 above), tensile strength values as low as 500 to 600 psi may be more appropriate than PII's values of 836 to 962 psi. If PII, and by extension FENOC, have assumed concrete shield building concrete tensile strength values that are too high, this could mean that cracking is much more widely distributed across the shield building structures than has been admitted. This contention is deserving of a hearing on the merits, to look into such safety significant questions.

PII's admission that "the strengths of concrete can decrease over time due to aging-related mechanisms such as freeze-thaw cycles and chemical attacks" bolsters Intervenors' arguments that the cracked concrete containment contention is aging-related, and points to the obligation of a full hearing on the merits.

PII listed a nineteenth area of NRC questioning:

> 19. Item 59: Can a radial/bending loads induced by off-center loads applied on the dome (e.g. uneven snow loads or unbalanced dead load for dome/parapet) be transmitted to the top of the shield building wall? If not explain. If so should this have been incorporated into the FE models?

PII responded by adding a new section XVII Additional Comments item 1 *(sic)* before Appendix I-page 92-93 (pp. 112-113/257 of .pdf), as follows [actually, item 3 responds to this question, not item 1 as PII indicated; the relevant item 3 states the following] (at p. 92):

> XVII. Additional Considerations
>
> The following are responses to issues raised after the report was finalized in its current form.
>
> . . . .3. An uneven snow load could transfer load to the top of the SB wall, but it wouldn't be any worse than the entire roof filling up with water. A previous vendor did a calc on the latter and the stresses were relatively small. This also wouldn't explain why there was cracking all the way down the wall, so it was never considered as a significant contributor to the laminar cracking.

PII's statement, "An uneven snow load could transfer load to the top of the SB wall, but it wouldn't be any worse than the entire roof filling up with water," provides no reassurance to the public interest in the integrity of the shield building. "The entire roof filling up with water" is very disturbing, considering the dome's documented cracking as early as 1976 and flaws identified in the dome's waterproof sealant identified by 1976. Any failure of the dome's/parapet's waterproof sealant would allow water to percolate down into the SB wall below. This top-down water flow could worsen cracking over time – that is, cause age-related degradation – due to rains, melting of snow, *etc.*,

which are common occurrences on the shoreline of the Great Lakes. So, if "an uneven snow load" is as bad as "the entire roof filling up with water," this is of great concern to Intervenors, not only due to the weight of the snow/water, but to the potential for water to flow through roof/sealant flaws into the shield building wall, causing further damage below.

PII's flippant response to NRC's very serious question is disconcerting. "The entire roof filling up with water," which from PII's response may be a relatively "routine" occurrence at Davis-Besse, is likely due to a bad water drainage design of the dome/parapet juncture. Standing water is documented in the photo included at Figure 4: "Top-Down Moisture Transport Mechanism" on page 19 of the PII revised root cause assessment report.

As documented at NRC's seventh area of questioning (Item 46), PII itself has admitted that "The second most likely scenario [root cause for shield building laminar cracking] is that during the blizzard, water intruded from the cracks in the dome of the structure and trapped in small gaps between the rebar and concrete. Upon freezing, the volume expansion of ice produced significant radial stresses that resulted in the observed cracking." The NRC then asked, "Is this scenario also identified and explained in the FENOC RCR [Root Cause Report]? If so where? If not, why not?"

"The second most likely scenario" for the root cause of shield building laminar cracking should not be so flippantly treated as routine by PII. Neither PII nor FENOC answered why this potentially significant "Top-Down Moisture Transport Mechanism" was not even mentioned in FENOC's root cause report.

The "calc" done by an unnamed vendor was not provided, not even in summary form. "Relatively small stresses" on a shield building as cracked and otherwise degraded as Davis-Besse's could be the straw that breaks the camel's back. "Cracking all the way down the wall" could be due

to an accumulation of "relatively small stresses" that, added together, have proven too much for the shield building to bear.

The uneven snow load stress risk is even more significant when considered in combination with the "out of plumb" shield building design flaw (the thirteenth area of questioning above, Item 52). Although FENOC has previously objected to Intervenors mentioning that Davis-Besse is located on the shoreline of Lake Erie, that fact remains: Davis-Besse, and its shield building dome, have been exposed to a large number of snow storms over the decades, including the Blizzards of 1977 and 1978, central to FENOC's root cause report of February 28, 2012, its revised root cause analysis report of May 16, 2012, and PII's revised root cause assessment report posted to ADAMS on May 24, 2012. PII has not addressed that combined stress of out-of-plumb design flaws in combination with uneven snow loading. As is the case throughout its revised root cause assessment, PII has not answered NRC's questions, and NRC has not required PII to answer its questions. Apparently, the task belongs to Intervenors, who hope to have such questions answered in a hearing.

PII acknowledged a twentieth area of NRC questioning:

> 20. Item 60: Why was this location and size of crack on the SB selected to evaluate crack propagation? Is it the highest stress location for this type of cracking, explain?

PII responded by adding to a new section XVII, Additional Comments, item 2, before Appendix I (PII report at p. 92-93, 112-113/257 of .pdf). However, it could well be that PII's reference to "Item 2" above was simply in error. PII's Item 4 in the same section seems more responsive to NRC's question:

> [Exhibit 56] [Page 79]. The size and location for the 30'x30' simulated "crack" was selected to approximate the same location as the physically observed 30' crack.

Intervenors' concern still remains, that PII has cherry-picked areas of the shield building for analysis that do not represent the areas with lowest margin of safety, and loads that do not represent the most damaging potential loads, especially in combination with other loads, especially considering the comprehensive damage already known in Davis-Besse's shield building which requires an accounting.

NRC put this twenty-first question to PII:

> 21. Item 61: Why wasn't the maximum design loading in the lowest margin areas of the SB assumed for this crack growth analysis (e.g. seismic loads/design wind loads including tornado driven missile impacts)? If the design loading was considered could the cracks propagate? *(e.g.* What combination of design and service loads could cause the existing cracks to propagate?)

PII claims to have responded by adding, in new section XVII Additional Comments item 3 before Appendix I (PII report pp. 92-93). However, Item 3, about uneven snow loads transferring load to the top of the SB wall, does not address this question, so PII's citation above seems to be in error.

Item 5 seems the most relevant answer to this question in the entire section XVII, Additional Considerations. It states:

> The thermal transient analysis conditions were chosen as the design load conditions because these thermal loads are the only conditions that produce radial stresses of any significant magnitude tending to open pre-existing cracks. Wind, seismic and tornado loads do not produce any significant stresses of any nature at the location of 30' "crack".

PII repeatedly ducks the NRC's safety-significant questions. Why wasn't the maximum potential loading assumed in PII's crack growth analysis for areas of the shield building with the lowest margin? Intervenors submit that PII, and by extension FENOC, may have cherry-picked less-vulnerable areas of the shield building, as well as incorporating smaller assumed loads into calculations, to avoid identifying areas of the shield building particularly vulnerable to crack propagation over time.

Intervenors are troubled by PII's downplays and denials of risks in the face of tough questions asked by NRC staff in documents obtained by Intervenors via FOIA. For example, Abdul Sheikh of NRC asked if a small stress might just be enough to fail the shield building 27 inches deep, all the way down to the inner rebar mat, just 3 inches from the inside face of the shield building. Pete Hernandez of NRC pointed out that the significant question does not have to do with architectural elements of the shield building, but rather whether or not the entire structure could collapse. PII responded that "wind, seismic and tornado loads do not produce any significant stresses of any nature at the location of 30' 'crack'." But what about a combination of adverse forces acting simultaneously on a severely compromised shielding building structure, not only at the 30' crack location, but also at equally vulnerable, or even more vulnerable, locations?

PII relates a twenty-second area of NRC questioning:

> 22. Item 62: States "Therefore it is not believed that the increased magnitudes in either the radial or maximum principal stresses are sufficient to propagate cracks that may have formed under normal thermal and environmental conditions, such as winter and summer.' What is the magnitude of the stress amplification assumed at the tip of the laminar crack front? And what is the level of tensile stress (mode I) or shear stress (mode II) is required to drive this crack based upon the stress concentrations? Work in Sweden that indicates non-linear FE [Finite Element] models have been used to predict cracking of reinforced concrete under shear loads. Why wasn't a similar FE model developed to evaluate the potential for growth of the existing cracking? Why isn't a more refined FE model or other applicable analysis needed as part of the corrective actions to monitor crack growth to ensure monitoring plans are adequate?

PII responded with this note added before XV Root Cause and Contributing Causes (page 87):

> Section 14 02 Conclusion
> As summarized in Table 6 the magnitude of maximum principal stresses increased a slight amount from σMP= 162 psi (No crack) to σMP= 184 psi (w/crack). There is only a marginal increase in the magnitude of radial stress, from σR= 76 psi (No crack) to σR= 92 psi (w/crack)…
> …Therefore it is not believed that the increased magnitudes in either the radial or maximum principal stresses are sufficient to propagate cracks that may have formed under normal thermal and environmental conditions, such as winter and summer. The stress

> concentrations, mode I and mode II stresses are calculated by the solver in the cracking models.

NRC is reasonable in asking PII why state-of-the-art Finite Element models, as used in Sweden, have not been used to analyze the Davis-Besse shield building risk for crack propagation.

NRC's questions ("Why wasn't a similar FE model developed to evaluate the potential for growth of the existing cracking? Why isn't a more refined FE model or other applicable analysis needed as part of the corrective actions to monitor crack growth to ensure monitoring plans are adequate?") show that Intervenors' request for a hearing on these aging-related matters is reasonable as well. PII's inadequate responses and FENOC's AMP fail to answer or account for the NRC's safety-significant, aging-related questions. The daily and seasonal thermal forces, as well as environmental stresses, could pose a challenge to the already multiply-challenged shield building over the 2017 to 2037 license extension period. PII and FENOC, have not adequately accounted for all the cumulative loads and stresses.

Finally, "it is not believed" is not an adequate quantitative, empirical, data base answer to such significant questions.

PII lists a twenty-third area of NRC questioning:

> 23. Item 63: Ice could not form in the main steam line room areas, where laminar cracking was identified. How did laminar cracking propagate into this area without ice formation and how long did this propagation take? (*e g*. minutes, hours, days, weeks?) Based on Exhibit 75 sub model near top of aux building roof, the cracking is not predicted to propagate once the crack has initiated due to differential thermal expansion and freezing process, so why did the crack propagate into the main steam line room? If this cannot be explained based upon the model developed why not?

PII responded by adding "in new section XVII Additional Comments item 4 before Appendix I - page 92-93." But Item 4's being referenced seems to be in error, yet again. Item 6 seems to be the one PII actually meant. Item 6 states:

> The presence of laminar cracks in the steam room does not contradict the freezing mechanism. In places where there is a very high density of rebar in a single plane (and therefore a very low density of concrete in that plane, like a perforated paper towel) it is possible for a crack to propagate due to initiation of cracking in an adjacent region. Based on the IR [Impulse Response] mapping data provided by Davis-Besse, the cracks around the main steam lines coincide with regions of very high-density rebar and have arrested near the boundary of these regions. This is entirely compatible with the most likely failure mode identified.

NRC's question bolsters Intervenors' filing of July 16, 2012, in which they documented multiple forms of cracking and other shield building degradation, located at diverse areas across the shield building, which challenged FENOC's Blizzard of 1978 root cause theory as all-explaining. The root cause of each kind of cracking and other shield building degradation must be accurately determined, so that adequate corrective actions and aging management plans can be put in place.

Even if the Blizzard of 1978 were to adequately explain the root cause of cracking in the Main Steam Line penetration areas, it does not solve the problem of corrective actions needed, including an adequate aging management plan. This should extend to other areas of the shield building with dense configurations of rebar, of course, as this is a design flaw/vulnerability located elsewhere, besides the Main Steam Line penetrations. Could these spots be the weakest link in the chain, the location(s) where a combination of adverse forces fails the shield building?

The NRC's twenty-fourth area of questioning follows:

> 24. Item 64: What was the exact number used as an input to the finite element model for the maximum depth of penetration where moisture levels would generate expansion of material vice contraction, (*e.g.* exceeded relative humidity of 93%). How sensitive is this model to this assumed moisture penetration depth? Specifically, if the depth is one inch less or one inch more, will it change the predicted crack initiation depth or growth rate?

PII responded by adding in new section XVII Comments item 7 before Appendix I - page 92-93 (incorrect item 5 was crossed out and replaced with item 7, with a handwritten note by Tom Henry dated 5/4/12) the following:

> 7. The exact depth of penetration used as input to the FE model varies. In "1D" areas, it is 4" or less. In "2D" areas, it is 14" or less. An inch one way or the other would shift the crack location about an inch - but a rigorous sensitivity study was not performed since we are not modeling growth rate.

Intervenors assert that a rigorous sensitivity study should have been, and still should be, performed. PII and FENOC should model growth rate, as this is essential for an adequate shield building aging management plan and monitoring program over time, including any 2017 to 2037 license extension period.

Admission by PII of 14 inch deep cracking is significant, given that the shield building walls are 30 inches thick. Even if PII is referring to a thicker area, such as flute shoulders - which is not clear - 14 inch deep cracking is of concern. Intervenors question, for both environmental protection and public safety reasons, the ability of those deeply-cracked locations on the shield building to fulfill their radiologically-critical function. The NRC's questions regarding "predicted crack initiation depth or growth rate" are potentially aging-related, and hence deserving of a hearing on the merits in this license extension application proceeding.

Before leaving this section, Intervenors point out that Items #1 and 2 were not addressed in PII's "Summary of Revisions." As was mentioned a number of times above, Section XVII was newly added, so it would seem that Items #1 and 2 were also newly added as well, just as were items 3-10, all of which were addressed above. Intervenors have the following comments on points #1 and 2:

> 1. The moisture penetration test procedure and test data are shown in Exhibit 52 Fig. 3. The analysis was shown in Exhibit 72. The tests, performed at the University of Colorado at Boulder, followed the procedure detailed in Exhibit 52 since there is no ASTM standard test appropriate for this purpose.

Intervenors are concerned that the shield building cracking at Davis-Besse is uncharted territory, as reflected in the PII statement that "there is no ASTM standard test appropriate for this purpose." A hearing would allow a more careful examination of these unique problems and risks.

> 2. Six core-bores revealed evidence of multiple laminar cracks in the same area of the outside face reinforcement. Performance Improvement International (PII) considers these to be a part of a single delamination process. As explained elsewhere, cracks in concrete follow the path of least resistance and may diverge an inch or two to bypass a large piece of strong aggregate. A crack may also split under the same condition and continue on both sides of the aggregate for a short distance. Another possibility is that two distinct cracks, originating to the left and right of the core, follow a slightly different path due to localized stronger aggregates. These cracks will either converge or one will terminate beyond the stronger area.

Intervenors believe that PII may have cherry-picked locations on the shield building with less significant cracking, while intentionally avoiding other areas that may have even more significant cracking.

NRC had inquired (as at the fourth area of questioning, Item 21 above) about micro-cracking, a phenomena that FENOC itself has acknowledged is related to age-related degradation and which was documented by Intervenors in their July 16, 2012 filing in this proceeding. PII's description of crack propagation (immediately above) related to NRC questions about Item 60 and it prompts Intervenors to wonder if the cracking described – which could be called macro-cracking rather than micro-cracking – is itself evidence of age-related degradation.

PII identified a twenty-fifth area of NRC inquiry, one that directly questioned the Blizzard of 1978 root cause at a very fundamental level:

> 25. [__Three letter REDACTION__] Item 1& 2: Finite element analysis evaluated a set of parameters that resulted in laminar cracking–necessary parameters. Explain the engineering judgment and assumptions that concluded 1978 blizzard conditions (rain, wind, temperature) resulted in the finite element analysis necessary parameters that resulted in shield building laminar cracking. Explain how 1978 blizzard conditions can explain cracking in the entire shield building? For example, if blizzard wind was in a single direction, how was water driven into all flute shoulders explained?

PII responded by adding, in new section XVII Additional Comments, item 8, before Appendix I, (incorrect item 6 was crossed out and replaced with item 8, with a handwritten note, apparently by Tom Henry dated 5/4/12, although the handwritten note is illegible) the following (at p. 93, 113/257 of .pdf):

> 8. A qualitative elimination analysis was performed for all possible events. The analysis concluded that the blizzard of 1978 was the only event that can possibly generate the damage. The externally necessary conditions are high speed wind driven rain which facilitated a large amount of moisture penetrated into the concrete. The internally (intrinsically) necessary condition is the expansive nature of the concrete upon the formation of ice under low temperatures. The blizzard of 1978 produced a "perfect storm" that combined all necessary conditions and make them sufficient to generate the damage. All necessary parameters (external loading parameters and internal material parameters) are random variables to a certain extent, such as wind speed, wind direction, temperature, coefficient of thermal expansion, compressive strength, and modulus of elasticity of concrete. Therefore, general trends of structural responses are more important than a specific response to a combination of input parameters. In order to simulate the general trend of the damage process by the FE method, the necessary parameters used as inputs for the FE analyses are either average values of test data obtained from the concrete cores available to PII during the project period or typical values collected based on our extensive literature search. The general trend of stress output of the FE analyses showed that the blizzard of 1978 was highly likely the event to cause large laminar cracks like those found in Davis-Besse shielding building. The blizzard of 1978 was the only event that produced a "perfect storm". Large forces were needed to propagate cracks through the aggregate and only two motivating forces were found to be capable of this - ice freezing and differential expansion due to ice freezing. In order for this scenario to happen, there need to be high winds and precipitation driving moisture into the concrete. The temperature outside has to drop to well below freezing. The blizzard of 1978 was the only event found to have all these factors in sufficient magnitude to cause large laminar cracks like those found at Davis-Besse. 2D moisture penetration in the shoulders (due to a high surface area to volume ratio) leads to more differential expansion under the shoulders. The presence of weak planes in the concrete (due to very high rebar density) gives the cracks a "perforated" path to propagate. Damage in the flute shoulders is concentrated on the southwest side of the building, which coincides with the predominant wind direction. Other parts of the building will still get wet. Based on the IR mapping, the laminar cracks that are not on the southwest side of the building are limited to regions with weak planes of concrete (due to high density rebar). Weak planes of concrete will require less force to initiate cracks. Therefore, the observed result is expected.

In the above passage, PII admits that areas of the shield building surface containing dense rebar which was not subjected to high wind, but was simply exposed to moisture, were also vulnerable to

severe cracking. For this reason, the entire shield building surface containing high density rebar should be carefully examined for cracking. Davis-Besse is located on the Lake Erie shoreline. It has been exposed to countless episodes of moisture drenching, followed by freezing temperatures. Combined with information on the substandard heat transfer characteristics of Davis-Besse's shield building concrete, discussed above, allowing deep freezing of water into the thickness of the shield building, the admission that high wind was not even needed to cause extensive cracking must be addressed across the structure. Weather-sealing the shield building 40 years late does not reverse the damage already inflicted. Nor does it preclude the need for a comprehensive aging management plan and corrective actions for damaged areas of the shield building which by PII's admission above extends to all areas of dense rebar, if not beyond.

Again and again, PII presents largely qualitative arguments, not quantitative analyses based on empirical data. Rigorous analysis, robust proof which supports arguments, is indispensable to prove these causation theories, especially given the high stakes, which include the catastrophic consequences of a shield building failure.

Intervenors again object to redactions which block their ability to fully understand even the questions NRC is asking, such as the two to three character redaction noted here, as well as immediately below, as well as in the final, twenty-seventh area of NRC questioning below.

PII lists a twenty-sixth area of NRC questioning:

> 26. [3 to 4 letter redaction] Item 3: Cracking postulated at 600 psi radial stress is one component of stress tensor. Clarify how this failure stress was developed. What is the significance with respect to actual tensile stress magnitude?

PII responded by adding, in new section XVII Additional Comments, item 9, before Appendix I (incorrect item 7 was crossed out and replaced with item 9, with a handwritten note, probably by Tom Henry dated 5/4/12, although the hand written note is illegible), stating as follows:

> The cracking models consider the entire stress tensor when calculating damage. This is done internally by the code. In all other models (non-cracking models), the failure stress being considered (regardless of its direction or magnitude) is strictly a means of comparison. The failure stress is not used as an input to any of the models other than the cracking models. The cracking models used a failure stress of 600 psi, which is not limited to radial stress.

Intervenors are concerned that PII's assumption of concrete strength values, which are over-optimistically high, would tend to underestimate cracking and other damage across the shield building structure. Such faulty assumptions and dangerous underestimates must be addressed in a hearing.

The twenty-seventh area of NRC questioning to PII was this:

> 27. [redaction] Item 4: Provide clarification with respect to shield building crack initiation, crack growth, and crack arrest. Why are the computer results reasonable and reflective of identified cracking?

PII responded by adding, in new section XVII Additional Comments, item 10, before Appendix I, (p. 94 of PII report, 114/257 of .pdf) the following:[7]

> The models that have been run to date produce results that are reflective of the observed damage based on IR mapping data. The laminar cracks occur in essentially the same locations in the models and in reality, including in the **shoulders on the southwest side of the building and in regions with very high planar rebar density, such as in the top 20' of the building and around the main steam line penetrations.** (Emphasis supplied).

Intervenors again object that PII not be allowed to cherry-pick select areas of the shield building to

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[7]Incorrect item 8 was crossed out and replaced with item 10, with a handwritten note, apparently by Tom Henry dated 5/4/12 which is legible; Intervenors assume that all the rest were his signatures or initiallings along with dates.

test, which fit its predetermined theory, but exclude testing other areas of the shield building structure that could also be cracked or otherwise damaged. NRC itself has questioned the logic of PII's and FENOC's Blizzard of 1978 root cause conclusion for sub-surface laminar cracking – given that areas not in the direction of wind driven rain are also cracked, inexplicably. But the Blizzard of 1978 cannot explain shield building dome cracking that was documented as early as 1976. Nor can applying weather sealant 40 years late reverse damage already inflicted, as through the top-down moisture penetration model, where cracks and weather sealant failures in the dome area have allowed moisture penetration via that route downwards – moisture that originated not only from the Blizzard of 1978, but other precipitation events on the Lake Erie shoreline over the course of years and perhaps even decades.

Intervenors urge that their cracked concrete containment and Severe Accident Mitigation Alternatives (SAMA) contentions are inextricably interlinked because FENOC assumes a functioning shield building in its SAMA analyses. Given the severe cracking and other degradation of the shield building, that assumption no longer holds water.

C. Legal Standards Regarding Admissibility Of Supplemental Information

1. The Contention Satisfies the NRC's Admissibility Requirements in 10 C.F.R. § 2.309(f)(1)

a. Brief Summary of the Basis for the Contention

The contention is based on the continuing technical information that has become public since October 2011 respecting cracking phenomena which were observed on the shield building at the Davis-Besse Nuclear Power Station. The early disclosures by FENOC concerning both the cause of the cracks, the extent of them, and their effects on the integrity of the shield buildling were

minimal and inaccurate. The utility set as a priority the restart of commercial power production at Davis-Besse, which was approved by the NRC commencing on December 2, 2011.

b. The Contention is Within the Scope of the Proceeding

It is not disputed that maintenance of the structural stability of the shield building is within the scope of this licensing proceeding. On April 5, 2012, FENOC proposed an aging management plan (AMP) and the NRC Staff insists that any aging-related aspects of the shield building are ameliorated by that AMP. "[W]ith respect to license renewal, under the governing regulations in 10 CFR Part 54, the safety review of license renewal applications is limited to the plant systems, structures, and components (as delineated in 10 CFR § 54.4) that will require an aging management review for the period of extended operation or are subject to an evaluation of time-limited aging analyses. As to the shield building, FENOC "must demonstrate that the 'effects of aging will be adequately managed so that the *intended function(s)* [as defined in § 54.4] will be maintained consistent with the CLB [current licensing basis} for the period of extended operation.'" *Nuclear Generation Co. and Entergy Nuclear Operations, Inc.* (Pilgrim Nuclear Power Station), CLI-10-14, 71 NRC __ (June 17, 2010) (slip op. at 8) (quoting 10 C.F.R. 54.21(a)(3)) (emphasis in original)).

c. The Issues Raised Are Material to the Findings that the NRC Must Make to Support the Action that is Involved in this Proceeding

The issues raised in this contention are material to the findings the NRC must make to support the action that is involved in this proceeding, in that the NRC must render findings pursuant to NEPA and to the Atomic Energy Act covering all potentially significant environmental and safety impacts. License renewal review focuses on "those potential detrimental effects of aging that are not routinely addressed by ongoing regulatory oversight programs." *Florida Power & Light Co.* (Turkey

Point Nuclear Generating Plant, Units 3 & 4), CLI-01-17, 54 NRC 3, 7 (2001); *Entergy Nuclear Generation Co. and Entergy Nuclear Operations, Inc*. (Pilgrim Nuclear Power Station), LBP-06-24, 64 NRC 257, 275-76 (2006). Before the NRC will grant a license renewal application, the applicant must reassess safety reviews or analyses made during the original license period that were based upon a presumed service life not exceeding the original license term. *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 & 4), CLI-01-17, 54 NRC 3, 8 (2001). The reassessment must "(1) show that the earlier analysis will remain valid for the extended operation period; (2) modify and extend the analysis to apply to a longer term such as 60 years; or (3) otherwise demonstrate that the effects of aging will be adequately managed in the renewal term." *Florida Power & Light Co.* (Turkey Point NuclearGenerating Plant, Units 3 & 4), CLI-01-17, 54 NRC 3, 8 (2001) (citations omitted).

D. Concise Statement of Facts or Expert Opinion That Support the Contention

The shield building cracking was unforeseen in FENOC's license renewal application, which presumed a structure surrounding the nuclear reactor which was fissure-free and not prone to failure in the form of up to 90% collapse of its rebar and concrete. Instead of the extremely limited laminar cracking identified in the February and May 2012 root cause analyses provided the NRC by FENOC, it appears that there is widespread micro-cracking in the shield structure, that there was cracking in the dome of the building in 1976, before the supposed "root cause" of the limited cracking admitted to exist *(i.e.*, the Blizzard of 1978). The NRC Staff, relying on FENOC's representations and those of its engineering consultant, PII, has determined that there is a significant chance of collapse of the structure's walls which could leave only a 3" thick building to contain a radiological accident.

e. A Genuine Dispute Exists with the Applicant on a Material Issue of Law or Fact

The Intervenors have articulated a genuine dispute with the applicant, FENOC, regarding physical adequacy of the shield building, which is the most critical structure at the Davis-Besse plant. There is extensive information, much of which is from FENOC's own consultant, and so, of an undisputed nature, suggesting the universal presence of cracking in the shield building from different origins (from the pouring and original drying of the concrete, the construction of the shield building significantly out of plumb, microcracking, moisture infiltration, carbonation and corrosion). Until there is a thorough, global investigation of the nature, extent and causation, the muted warnings of the NRC Staff stand as creating a genuine dispute of fact.

2. The Contention Is Timely Pursuant to 10 C.F.R. § 2.309(f)(2)

The contention meets the timeliness requirements of 10 C.F.R. § 2.309(f)(2), which call for a showing that:

> (i) The information upon which the amended or new contention is based was not previously available;
>
> (ii) The information upon which the amended or new contention is based is materially different than information previously available; and
>
> (iii) The amended or new contention has been submitted in a timely fashion based on the availability of the subsequent information.

Id.

Intervenors satisfy all three prongs of this test. First, the information on which amendment or supplemention of the contention is sought is new and materially different from previously available information. A new contention may be filed after the deadline found in the notice of hearing with leave of the presiding officer upon a showing that: (i) The information upon which the amended or new contention is based was not previously available; (ii) The information upon which the amended or new contention is based is materially different than information previously available;

and (iii) The amended or new contention has been submitted in a timely fashion based on the availability of the subsequent information. 10 C.F.R. § 2.309(f)(2).

Intervenors respectfully submit that their amended/supplemental facts are timely submitted under the Commission's standard in 10 C.F.R. § 2.309(f)(2)(i)-(iii). As supplemented/amended, Contention 5 meets the NRC's three-part standard for a timely contention. The information on which the contention is based was not previously available. PII's report, "Root Cause Assessment: Davis-Besse Shield Building Laminar Cracking, Vol. 1," was added to the NRC's ADAMS system on May 24, 2012 as ML12138A037. The information on which the contention is based is materially different than information previously available, *see* 10 C.F.R. § 2.309(f) (2)(ii), because it relates to findings and provides facts which did not exist when Intervenors moved for admission of Contention 5 in January 2012. This amendment/supplementation of Contention 5 is timely because it is filed within sixty (60) days of the PII report's May 24 posting date and conforms with the ASLB's Initial Scheduling Order. *Shaw Areva MOX Services, Inc.* (Mixed Oxide Fuel Fabrication Facility), LBP-08-10, 57 NRC 460, 493 (2008). Intervenors have acted in a manner which is timely according to 10 C.F.R. § 2.309(f)(2)(iii).

If a contention satisfies the timeliness requirement of 10 C.F.R. 2.309(f)(2)(iii), then, by definition, it is not subject to 10 C.F.R. 2.309(c), which specifically applies to nontimely filings. The three (f)(2) factors are not mere elaborations on the "good cause" factor of Section 2.309(c)(1)(i), since "good cause" to file a nontimely contention may have nothing to do with the factors set forth in (f)(2). *Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear Operations, Inc*. (Vermont Yankee Nuclear Power Station), LBP-06-14, 63 NRC 568, 573 (2006).

D. Certificate of 10 C.F.R. § 2.323(b) Consultation

Counsel for Intervenors, along with Beyond Nuclear's designated representative, participated in a telephone conference concerning the prospective contents of the within Motion on July 13, 2012 with counsel for the NRC Staff and counsel for FirstEnergy Nuclear Operating Corporation. Following that conference, FENOC's counsel has stated that FENOC will oppose this Motion. The NRC Staff's counsel indicated that NRC Staff does not oppose the filing of the motion, but that based on the information from the consultation email of Intervenors, and the phone conference, the Staff does not have enough information at this time to take a position on the admissibility of the proposed contention. Further, he stated that the Staff will respond to the contention in accordance with 10 C.F.R. 2.309, when filed.

E. Conclusion

Intervenors have met all preconditions to be granted leave for receipt of the within information into the record of this matter to amend and/or supplement their Motion for Admission of Contention 5. FENOC has offered up a very partial explanation to widespread shield building cracking which ignores or downplays forms of structural degradation besides sublaminar corrosion cracking. Moreover, the NRC Staff suggests that the state of cracking of the shield building is such that even a mild to moderate earthquake event could cause loss of 90% of the wall mass, which would comprise a tremendous failure of the structure as a protective barrier between Davis-Besse's nuclear reactor and the outer atmosphere, land and water.

WHEREFORE, Intevenors pray the Licensing Board grant them leave to amend and/or supplement their proffered Contention 5 in the particulars stated.

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
Before the Atomic Safety and Licensing Board

In the Matter of	)	
		Docket No. 50-346-LR
First Energy Nuclear Operating Company	)	
(Davis-Besse Nuclear Power Station, Unit 1)		July 23, 2012
.	)	

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CERTIFICATE OF SERVICE

We hereby certify that a copy of the "INTERVENORS' FOURTH MOTION TO AMEND AND/OR SUPPLEMENT PROPOSED CONTENTION NO. 5 (SHIELD BUILDING CRACKING)" was sent by me to the following persons via electronic deposit filing with the Commission's EIE system on the 23rd day of July, 2012:

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Hernandez, Pete

From: Hernandez, Pete
Sent: Thursday, November 17, 2011 7:58 AM
To: Sanchez Santiago, Elba
Subject: Davis Besse Operability question

Good afternoon Michele,

I understand that the question of Operability vs design basis was posed and that if this issue was in operations space, are qualitative evaluations the extent of review required by the licensee?

To answer that, the distinction between Operability and Functionality needs to be understood. The most clear way I've had it explained is that the determination of Operability is tied to the Tech Specs for the specific plant. If the Tech Specs are met, then it is operable. (An operability determination is usually prompted by degraded conditions, nonconforming conditions or the discovery of an unanalyzed condition.) Functionality is tied to the design bases documented in the FSAR and thereby tied to the Current Licensing Basis.

From IMC9900

> "If an SSC described in TSs is determined to be operable even though a degraded or nonconforming condition is present, the SSC is considered "operable but degraded or nonconforming." An SSC that is determined to be operable but degraded or nonconforming is considered to be in compliance with its TS LCO, and the operability determination is the basis for continued operation. The basis for continued operation should be frequently and regularly reviewed until corrective actions are successfully completed."

The licensee decided to not enter into an Operable but Degraded or Nonconforming determination and that the cracking issue is a design basis question hence functionality.

Speculating: The cracks in the building qualify as an unanalyzed condition so for the licensee to Operate with a degraded or nonconforming condition, they would have to develop a plan to fix the issue through their CA process. However, the licensee has stated that the SB is Operable as is, so there is nothing to fix. This still leaves the issue of the cracks unresolved so they are trying to prove that the cracks do not affect the functionality of the building. This led them to the design basis evaluations.

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Hernandez, Pete

From: Hernandez, Pete
Sent: Friday, November 04, 2011 9:35 AM
To: Sanchez Santiago, Elba
Cc: Zimmerman, Jacob; Mahoney, Michael
Subject: Questions about Davis Besse Shield Building Report from DORL

Elba, here are the questions I had about the report from Davis Besse. The calculations were a bit out of my range but, I had questions about their general methods. The Tech folk should have their questions over to you this morning also.

Thanks,

Pete

Questions about Davis Besse Shield Building Report

C-CSS-099.20.054

Objective or Purpose (paragraph 3): In this calculation the structural integrity of the SB is evaluated considering the presence of an interfacial/circumferencial crack between the SB structural concrete shell (i.e., the 30" thick reinforced concrete SB) and each architectural flute shoulder (16 flute shoulders in total), as decribed in Attachment B.

This description makes me think that they are looking at a single crack going in a circle. From what I understood the crack is pervasive along the entire surface, spidering in all directions, similar to a pane of tempered glass breaking. The description in Attachment B addresses only the crack at the opening and assumes that the crack is right along the rebar line. The core bores have shown that the cracks are at different depths so this doesn't seem to capture the current situation. Throughout the calculation, the word Crack, singular, is used. They also mention that the extent of the crack is only 10'-12'. This seems to greatly downplay the issue.

Scope of Calculation/Revision (bullet 4): Maximum concrete crack width under flexure is calculated and compared with the allowable value (Section 7.5). Note that this maximum crack width evaluation only applies to the structural concrete (i.e., the 30" thick reinforced concrete SB shell). In particular, the width of any cracks in the 16 nonstructural architectural flute shoulders is not addressed.

At this point core bores of only the shoulders have been taken. So the only crack widths we are aware of are those in the shoulders, which are not being addressed. How can an analysis be done on the structurally credited concrete if no data from that area, in the form of core bores, has been taken? Shouldn't the structural integrity of the shoulders be calculated as well?

Section 3.0 Methodology (last sentence): Thus, this calculation focuses on the structural integrity of the reinforced concrete within and around the RCVH/SGs construction opening, once it is restored.

This seems to say that they are just doing calculations for the new concrete that is and ignores the rest of the building altogether. Is that right?

Section 3.1 Construction sequence (page 6, second paragraph): However, the vertical reinforcement next to each flute (i.e., in a vertical strip approximately 10 ft wide) is conservatively ignored for evaluating the structural integrity of the SB under mechanical loads...

This says to me, that they are ignoring the shoulders, if they are ignoring all that concrete, it seems to be the opposite of conservative for evaluating the mechanical loads.

C-CSS-099.20.055

Objective or Purpose: The purpose of this calculation is to demonstrate that during a seismic event, with the development of the crack in the architectural flute shoulder, the capacity of rebar(s) can still provide adequate anchorage thus prevent cracked concrete piece from falling, and therefore Seismic II/I condition can be maintained.

I think the greater concern is will the SB stay standing and not whether or not the decorative concrete will fall off. Because the licensee has not performed core bores to see if there is cracking in the credited concrete, do they have a basis to say that the structural concrete will maintain a Seismic II/I condition?

B/9

This use of singular terminology also discounts this calculation because it seems that they are looking at only 1 crack and 1 shoulder or 1 flute. Because cracks have been found through multiple core bores, shouldn't the appropriate calculations account for the combined effects of cracks in all the shoulders and not just one by the opening and not just individually?

Section 6.2 (page 7): Based on Impulse Response testing, the actual crack length is 10 to 12 feet long.
From what I understand, IR mapping is only an indicator, but must be validated by core bores. Does basing all the calculations on a length of a 12 foot crack discount the calculations altogether, because we have indications of cracks at distances greater than 12 feet. This also seems to assume that there is only 1 crack and not many as the core bores seem to prove. Isn't IR mapping only useful at a limited depth too, so that using it to evaluate a 48" thick piece of concrete is not realistic?

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Sakai, Stacie

From: Sheikh, Abdul
Sent: Tuesday, November 22, 2011 10:51 AM
To: Sanchez Santiago, Elba
Cc: Hoang, Dan; Manoly, Kamal; Sakai, Stacie
Subject: Questions for the Conference Call

There are several documents (summary report, new calculation 056) that have different assumptions and approaches. I did not have enough time to review the calculation (196 pages). However, the basic questions are as follows:

1. What is the actual condition of the concrete 20 feet below the spring line based on field verification.
2. Calculation C-CSS-089.20-056, page 5 states in the assumption section that, "because the bond strength of reinforcement with laminar cracking next to it cannot be quantified, outside face hoop reinforcement in these regions is treated as ineffective --- for ultimate strength calculations." If this assumption is correct only 3-4 inches of the concrete on the inside face can be used in the structural analysis. In the response to the questions, the applicant stated that, " Since we assume that outside reinforcement is to be treated ineffective in carrying any additional stress beyond 12.4 ksi, under accident thermal loads that may cause stresses in excess of what the rebar can carry (assumed 12.4 ksi), the reinforcement is assumed to detach itself from the outer section of the shell." These statements seems to be contradictory. In addition, I am concerned that the concrete will fail in this region due to bending in this region even under small loads.
3. Lap splice issue. ACI 318-63, section 805 (b) states that, "---however, length of lap for deformed bars shall be not less than 24, 30, and 36 bar diameters for specified yield strength of 40,000, 50,000, and 60,000 psi, respectively."
4. At places in the licensee documents, it is stated that due to staggered lap rebar splices, only 50 percent of the rebars are considered effective. If this is the assumption, stress used for lap splice calculation should account for 100 percent increase in the stress.
5. The licensee justification for ignoring the dead (DL) and normal thermal (To) in calculation of rebars splice does not appear to be justified. The stresses due to dead load and thermal loads will be locked in the rebars and cannot be ignored.
6. The licensee considers the allowable stress in the rebar to be 60 ksi and ignores a phi factor (0.9) in his evaluation for lap splice. In addition, the licensee has not accounted for any additional uncertainty due the field conditions.
7. Licensee response to question 1 states, "On a conference call with Drs Darwin and Sozen both indicated that the capacity of the reinforcement steel after the concrete is cracked (in the 5-10 mil range) is still 20 to 30%. This is based on pull tests of straight bars under tensile loads." I am not aware of any pull tests carried out with a crack in the plane of the rebar. Can the licensee provide any documentation for this statement.
8. The licensee is using numerous assumptions in his summary report and calculations that are not described in the UFSAR and ACI 318-63, and still calls it a design basis calculation. Can the licensee provide justification for this approach.

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