

**UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION**

In the matter of

FirstEnergy Nuclear Operating Co.) May 25, 2009
Beaver Valley Power Station Unit 1) Docket No. 50-334 and 50-412
License Renewal for Beaver Valley Units 1 and 2)

DECLARATION OF ARNOLD GUNDERSEN
SUPPORTING CITIZEN POWER'S PETITION

I, Arnold Gundersen, declare as follows:

1. My name is Arnold Gundersen. I am sui juris. I am over the age of 18-years-old.
2. Citizen Power has retained me as an expert witness in the above captioned matter, and my declaration is intended to support the Petition of Citizen Power.
3. I have a Bachelor's and a Master's Degree in Nuclear Engineering from Rensselaer Polytechnic Institute (RPI) cum laude.
4. I began my career as a reactor operator and instructor in 1971 and progressed to the position of Senior Vice President for a nuclear licensee. A copy of my Curriculum Vitae is attached. (*Exhibit 3*)
5. I have qualified as an expert witness before the Nuclear Regulatory Commission (NRC) Atomic Safety and Licensing Board (ASLB) and Advisory Committee on Reactor Safeguards (ACRS), in Federal Court, before the State of Vermont Public Service Board and the State of Vermont Environmental Court.
6. I am an author of the first edition of the Department of Energy (DOE) Decommissioning Handbook.

7. I have more than 35-years of professional nuclear experience including and not limited to: Nuclear Plant Operation, Nuclear Management, Nuclear Safety Assessments, Reliability Engineering, In-service Inspection, Criticality Analysis, Licensing, Engineering Management, Thermohydraulics, Radioactive Waste Processes, Decommissioning, Waste Disposal, Structural Engineering Assessments, Cooling Tower Operation, Cooling Tower Plumes, Consumptive Water Loss, Nuclear Fuel Rack Design and Manufacturing, Nuclear Equipment Design and Manufacturing, Prudency Defense, Employee Awareness Programs, Public Relations, Contract Administration, Technical Patents, Archival Storage and Document Control, Source Term Reconstruction, Dose Assessment, Quality Assurance and Records, Configuration Management, Whistleblower Protection, and NRC Regulations and Enforcement.
8. My declaration is intended to support the Petition by Citizen Power and is specific to issues regarding FirstEnergy Nuclear Operating Company's application to extend Beaver Valley Unit 1 Power Station's operating license for an additional 20 years.
9. Beaver Valley Unit 1 is a Westinghouse three loop Nuclear Steam Supply System with a Stone & Webster designed "sub-atmospheric containment." It received its operating license to generate electricity on July 2, 1976.¹
10. According to NUREG/CR 5640, the *Nuclear Power Plant System Sourcebook*:
"Sub-atmospheric containments are only found at seven Westinghouse PWR plants, six 3-loop plants, and one 4-loop plant."
11. Stone & Webster Engineering Corporation designed all sub-atmospheric containment systems. The six three-loop sub-atmospheric units are Beaver Valley 1 and 2, North Anna 1 and 2, and Surry 1 and 2. Stone & Webster's last sub-atmospheric containment is at Millstone Unit 3, a Westinghouse four-loop unit.
12. As a former Northeast Utilities employee who worked on the Millstone Unit 3 engineering, design, and construction, I have personal knowledge of Stone &

¹ <http://www.nrc.gov/info-finder/reactor/bv1.html>

Webster's sub-atmospheric design. Moreover, in 2008, I provided written testimony to the NRC regarding Millstone Unit 3 sub-atmospheric containment. (*Exhibit 2*)

13. Furthermore, I briefed the NRC ACRS on the problems and contradictions associated with the NRC's analysis of sub-atmospheric containments.

14. As the lead licensing engineer for Northeast Utilities' Millstone Power Station Unit 3 during the 1970's, I was responsible for coordinating the analysis for the PSAR (Preliminary Safety Analysis Report), which formed the original design basis of the Millstone Power Station Unit 3 including its Containment. This interface was among Millstone's structural mechanical, electrical, construction, and operations personnel as well as the architect Stone & Webster and the NSSS vendor Westinghouse. Millstone Power Station Unit 3 was originally designed to be a "Sub-Atmospheric Containment." [In this instance my testimony is that of a fact witness² in addition to my overall testimony as an expert witness in my Millstone Unit 3 Declaration (*Exhibit 2*).]

15. In my 2008 expert witness report to the NRC ACRS, I identified generic issues with sub-atmospheric containments. The issues of critical concern to both the engineering and operations staff regarding the Sub-Atmospheric Containment were:

15.1. Members of the operations staff, who worked within the Containment, were repeatedly subjected to the adverse effects of high temperature and low oxygen.

15.2. The small size of the Containment Building severely limited space for equipment and also complicated accident analysis.

² According to the Department of Justice United States Attorneys' Manual Title 3, Chapter 3-19.111 An expert witness qualifies as an expert by knowledge, skill, experience, training or education, and may testify in the form of an opinion or otherwise. (See Federal Rules of Evidence, Rules 702 and 703). The testimony must cover more than a mere recitation of facts. It should involve opinions on hypothetical situations, diagnoses, analyses of facts, drawing of conclusions, etc., all which involve technical thought or effort independent of mere facts. And according to Chapter 3-19.112 Fact Witness A fact witness is a person whose testimony consists of the recitation of facts and/or events, as opposed to an expert witness, whose testimony consists of the presentation of an opinion, a diagnosis, etc
http://www.usdoj.gov/usao/eousa/foia_reading_room/usam/title3/19musa.htm#3-19.111

15.3. Significant construction problems relating to the placement of concrete and rebar were caused by the Containment's small size.

15.4. Minimal analytical data regarding the long-term strength of the building's concrete and its continual exposure to the combination of high temperatures, low pressure, and low specific humidity within its sub-atmospheric Containment as it has aged has led to doubts and questions regarding the strength of this critical safety-related structure in the event of a nuclear accident.

16. Following my ACRS testimony, the ACRS questioned a *containment specialist* staff member of NRC as to whether the NRC even has the capability to analyze a sub-atmospheric containment. According to the NRC *containment specialist*, the NRC cannot accurately analyze Containment systems.

The NRC staff member *containment specialist* said,

“It's sort of difficult for us to do an independent analysis. It takes time. We're not really set up to do it. The other thing you have to realize, too, for containment, which isn't as true in the reactor systems area, is that **we don't have the capability.**” (Page 88, ACRS Transcript, July 9, 2008, lines 6-11.) [*Emphasis added*]

17. From 1976 until 2002, Beaver Valley Unit 1 (BV1) was operated with a sub-atmospheric containment building. In my opinion, Stone & Webster's similar patents³ provide two important considerations that apply directly to Beaver Valley's design. Those two considerations are that concrete is considered

³ According to one of S&W's patents, “A Sub-atmospheric double containment system is a reinforced concrete double wall nuclear containment structure with each wall including an essentially impervious membrane or liner and porous concrete filling the annulus between the two walls. The interior of the structure is maintained at sub-atmospheric pressure, and the annulus between the two walls is maintained at a sub-atmospheric pressure intermediate between that of the interior and the surrounding atmospheric pressure, during normal operation. In the event of an accident within the containment structure the interior pressure may exceed atmospheric pressure, but leakage from the interior to the annulus between the double walls will not result in the pressure of the annulus exceeding atmospheric pressure so that there is no net outleakage from the containment structure. US Patent 4081323 Issued on March 28, 1978 to Stone & Webster Engineering Corp.

porous and all boundaries leak to some extent. On page 1 of the footnoted patent, Stone & Webster considers the concrete to be “*porous*”, and on page 8 of the cited patent, Stone and Webster stated, “...*all boundaries leak to some extent...*”.

18. In a sub-atmospheric containment, the air pressure in the containment is approximately 4 psi⁴ below the pressure outside the containment liner.
19. During the past four years the evidence I reviewed shows that several age related corrosion problems have impacted BV1’s containment system.
20. According to Beaver Valley Senior Resident Inspector David Werkheiser⁵, May 19, 2009, the first documented containment liner problem at BV1 was uncovered during the BV1 2006 steam generator replacement outage.
 - 20.1. Specifically, NRC Senior Resident Inspector Werkheiser said that when the containment liner was cut and removed to allow the steam generator replacement, Beaver Valley personnel noticed three locations or pockets on the “outside” of the cut portion of the liner where significant corrosion was present.
 - 20.2. According to Werkheiser, FirstEnergy’s BV1 attributed these “pockets” to construction problems dating back to the early 1970’s. Werkheiser also noted that in FirstEnergy’s analysis, the “pockets” or voids appear to have been caused by improper vibration of the concrete as it was being poured.
 - 20.3. Furthermore, Werkheiser noted that FirstEnergy’s analysis showed that over time these “pockets” had allowed moisture to accumulate and gradually corrode the “outside” of the liner.
 - 20.4. Finally, Werkheiser confirmed that the three corrosion locations were analyzed and repaired prior to start-up in 2006 in accordance with:

⁴ pounds per square inch

⁵ Telephone conversation between Beaver Valley Senior Site Resident Inspector David Werkheiser and Arnold Gundersen, expert witness nuclear engineer, May 19, 2009 12:33 pm.

- Duquesne Light Company Calculation 8700-DSC-156W, 2/26/91;
- Liner Minimum Wall Thickness S&W Calculation 11700-EA-41, 11/3/71;
- Duquesne - Beaver Valley Unit 1 – Reactor Containment Liner Stress Analysis and repaired before the Unit started up in 2006.

21. In my opinion, the data I reviewed from the FirstEnergy BV1 SER and outage report indicates problems with the BV1 inspection techniques. For more than 30-years, BV1's visual, ultrasonic and integrated leak-rate inspection techniques were unable to detect these three voids and their associated corrosion until 2006, though the voids and corrosion clearly existed well before then.

22. When the steam generator was replaced in 2006, the 17' x 21' piece of liner which was removed represents, according to my calculations, approximately three percent of the total containment liner.

22.1. Given that the voids are randomly positioned, when I applied a ratio of the containment surface area to the piece removed, a basic statistical analysis showed that if three voids were found behind a 17'x 21' section, there may be as many as 99 (ninety-nine) more voids that are similarly impacted by corrosion, but remain hidden behind the residual containment liner.

22.2. By failing to reexamine the full liner in 2006 after detecting three corrosion sites, I believe that FirstEnergy and the NRC made analytical errors by not analyzing whether the sampling density is sufficient to make a reasonably valid conclusion. By not inspecting for more corrosion, in other words, not looking for evidence of the corrosion problem does not prove that corrosion does not exist and that the containment system is sound.

23. BV1 documented a second containment liner problem on April 23, 2009, when the company filed event report 45015 with the NRC. According to BVI event report 45015 *Damaged Area In Containment Liner*:

"On April 21, 2009 during the Beaver Valley Power Station Unit No.1

(BEAVER VALLEY PS-1) refueling outage, an ASME XI Section IWE General Visual examination was performed on the interior containment liner. A suspect area was identified at the 738 foot elevation level of containment. This area was approximately 3 inches in diameter and exhibited blistered paint and a protruding rust product. At approximately 1015 hours on April 23, 2009 after cleaning the area and removal of the corrosion products, a rectangular area approximately 1 inch (horizontal) by 3/8 inch (vertical) was discovered that penetrated through the containment steel liner plate (nominal .375 inch thickness). The BEAVER VALLEY PS-1 containment design consists of an internal steel liner that is surrounded by reinforced concrete.”

"With the plant currently shutdown and in Mode 6, the containment as specified in Technical Specification 3.6.1 is not required to be operable. The cause of this discrepancy is currently being evaluated.

"This is reportable pursuant to 10 CFR 50.72(b)(3)(ii)(A) as a condition of the principal safety barrier (i.e., containment) being seriously degraded."

23.1. In my opinion, it is important to note once again that all visual, ultrasonic and integrated leak-rate inspection techniques at BV1 *failed to detect the incipient passive failure of a key safety structure before the full perforation of the steel liner.*

24. FirstEnergy claims that the “root cause” of both the BV1 2006 containment liner corrosion and the 2009 gross containment liner failure may be related to construction problems that occurred more than 33-years ago. However, the evidence I examined shows that this purported *root cause* analysis is simplistic for several reasons:

24.1. In the National Association of Corrosion Engineers (NACE) book⁶ *Corrosion Basics*, Pierre R. Roberge defines the electrochemistry of corrosion as resulting “from the overwhelming tendency of metals to react electrochemically with oxygen, water, and other substances in the aqueous environment”.

⁶ *Corrosion Basics: An Introduction*, 2nd Edition, by Pierre R. Roberge, 2006 by NACE Press Book, 364 pages, 77 tables, 292 figures hardbound, ISBN: 1-57590-198-0

- 24.2. Therefore, in order for any corrosion to occur, there must be both moisture and oxygen present during which the corrosion reaction would occur. In my expert opinion, if this corrosion issue were solely due to construction problems that occurred more than 33-years ago, there would not have been enough oxygen to cause the identified corrosion. Thus, there must be a secondary source of oxygen.
- 24.3. Neither the construction voids between the liner and the concrete, which was the purported BV1 2006 reason for containment corrosion, nor BV1's 2009 claim, that a block of wood left from construction, is the *cause* of this recent gross containment failure, because neither accounts for the significant oxygen and moisture buildup that must have occurred. I believe that both FirstEnergy and the NRC have failed to address the underlying issue, which is how did the accumulated moisture and oxygen infiltrate the containment system for such an extensive period of time as to perpetuate a serious corrosion reaction.
25. No root cause analysis to date has addressed moisture and oxygen buildup behind the liner, or why such a buildup occurred at only four very specific locations. The failure to conduct a root cause analysis implies that the four sites of corrosion identified during the past three years may be an anomaly. Rather, I believe that a root cause analysis must investigate in an in-depth fashion the possibility of systemic corrosion issues which may be even greater than 99 corrosion "pockets" on the "outside" of the containment liner rather than limited to these four recently discovered random sites.
26. As discussed above, BV1's sub-atmospheric containment design is unique. In my opinion, it is possible that the pressure differential between the outside moist air and the sub-atmospheric conditions within the containment could act as the driving force to draw moisture and oxygen through the porous concrete into construction voids and wood adjacent to the liner. Therefore, I believe this sub-atmospheric design may be the *root cause* of the oxygen and moisture buildup behind the liner. A thorough *root cause analysis* must consider what impact the sub-atmospheric containment had upon the accumulation of oxygen and moisture between the liner and the porous concrete.

27. In summation, I found the incomplete analytical evidence in the FirstEnergy BV1 and the NRC assessments of BV1's containment failures to be simplistic and believe such incomplete analysis puts an undue risk on public health and safety. In my opinion, an in-depth analysis of the corrosion problems that exists between the liner and the porous concrete may uncover systemic failure mechanisms.
28. Moreover, I believe the breach of this containment liner with no prior warning following repeated and various types of containment inspections which occurred for more than 33-years has broad nuclear policy and safety ramifications, for BV1, Beaver Valley Unit 2 and the other sub-atmospheric containments nationwide.
29. The evidence I reviewed also shows significant problems, therefore, I believe that corrective actions are appropriate, including, but not limited to:
 - 29.1. The prompt 100% ultrasonic inspection of the entire liner at BV1 due to the fact that more than 33-years of visual inspection and fractional ultrasonic testing failed to detect the 2009 corrosion until the liner failed.
 - 29.1.1. In my opinion, the liner failure implies that visual and partial ultrasonic techniques are inappropriate for liner inspections under any conditions.
 - 29.1.2. In my assessment, the Beaver Valley liner degradation and/or failures of both 2006 and 2009 indicate a gross breakdown in Quality Assurance (QA) procedures during the construction phase of BV1.
 - 29.1.3. Based upon my knowledge of the construction processes involved in pouring a sub-atmospheric containment, the QA process applied during the BV1 construction repeatedly missed opportunities for this piece of wood to have been discovered and removed.
 - 29.1.4. If the failure discovered in 2009 existed in 2006, an Integrated Leak rate Test in 2006 failed to detect incipient failure implying that slow, controlled pressurization of the containment in that test is inadequate to detect incipient

failure.

29.2. It is my position that the 20-year life extension of the Beaver Valley Units 1 and 2 should be put on hold until these significant programmatic Aging Management problems have been analyzed and resolved.

29.2.1. The visual, ultrasonic and integrated leak test inspection failures show programmatic weakness in the aging management systems upon which FirstEnergy has relied upon for its Beaver Valley Units' license extensions.

29.3. In my opinion, if the 100% UT inspection process discovers other construction voids, then the containment liner should be reanalyzed to determine the operability BV1 in order to ascertain any overall weakening of the liner.

29.3.1. An analysis of the Containment liner will ascertain its ability to withstand seismic stress and limit radiation releases, and the NRC has informed the ACRS of its inability to perform a containment analysis, I believe that an independent National Lab should perform this analysis.

29.4. Likewise, I believe that Beaver Valley Unit 2 (BV2) should also be inspected using 100% ultrasonic techniques, given that BV1 and BV2 have the same design, were built by the same contractor, have the same inspection program, and the same Aging Management Program.

30. Furthermore, it is my conclusion that these events at BV1 also have critical ramifications for the entire U.S. nuclear industry, but especially for PWRs.

30.1. In my opinion, the Containment Breach at BV1 in 2009 was the *Passive Failure* of one of the most important safety barriers in a nuclear power plant.

30.1.1. The nuclear industry has heretofore considered such containment liner failures virtually impossible.

30.1.2. NRC Risk Informed Decision Making does not take the likelihood of

Passive Failure of the Containment into consideration.

- 30.1.3. Given the generic nature and risk to public health and safety due to *containment breach*, I believe that the NRC should order 100% Ultrasonic Testing of all PWR containment liners.
31. In my opinion, FirstEnergy's inability to detect the most recent failure (2009) of the containment liner prior to perforation, as well as its inability to detect three other corrosion sites discovered in 2006, may indicate one of two possible failure scenarios.
- 31.1. If the 2006 and 2009 corrosion events grew slowly and began during construction, I believe this implies that during the 35-years since construction, neither the visual, ultrasonic, nor integrated leak rate testing have been adequate to detect incipient containment liner failure.
- 31.2. The second possibility is that visual, ultrasonic and integrated leak rate testing do indeed work, but that through wall liner failure can propagate much more quickly than anticipated between inspection intervals.
- 31.3. Both of these scenarios are equally troubling to me, as one indicates that ANY existing inspection regime has been inadequate, and the second indicates rapid failures are possible between inspections whose corrosion growth mechanisms have yet to be determined.
32. Given either scenario, it is my professional opinion that the NRC must modify the Beaver Valley SER and AMP to include a full ultrasonic inspection and root cause analysis prior to license extension.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Executed this day, May 25, 2009 at Burlington, Vermont.



Arnold Gundersen, MSNE

STATE OF VERMONT
COUNTY OF CHITTENDEN) ss.

I HEREBY CERTIFY that on this 25th day of May 2009, personally appeared Arnold Gundersen resident of Burlington Vermont, who is personally known to me or who produced the following identification, and he swore, subscribed, and acknowledged before me that he executed the foregoing as his free act and deed as an expert witness of said case, for the uses and purposes therein mentioned, and that he did take an oath.

In witness whereof, I have hereunto set my hand in the County and State aforesaid:

OFFICIAL NOTARY 

NOTARY PUBLIC STATE OF VERMONT

MY COMMISSION EXPIRES: 2/2010