ATTACHMENTS TO BEYOND NUCLEAR'S HEARING REQUEST AND PETITION TO INTERVENE

Attachment 1 – Declaration of Ernest Eric Guyll (Oct. 20, 2018)

Attachment 2 – Declaration of John S. Adams (Oct. 29, 2018)

Attachment 3 – Declaration of Virginia Topkis (Nov. 9, 2018)

Attachment 4 – Declaration of David A. Lochbaum (Nov. 16, 2018), including attachments:

- Curriculum vitae
- Expert report, Proposed Subsequent License Renewal of Peach Bottom Units 2 and 3: Exelon's Aging Management Programs Fail to Provide Adequate Measures for Consideration of Operating Experience Throughout the Period of Extended Operation (Nov. 16, 2018)

Attachment 1

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

IN THE MATTER OF EXELON GENERATION COMPANY, LLC PEACH BOTTOM UNITS 2 & 3	)	DOCKETS 50-000277 & 50-000278 SLR

DECLARATION OF ERNEST ERIC GUYLL

Under penalty of perjury, Ernest Eric Guyll declares as follows:

1. My name is Ernest Eric Guyll. I am a member of Beyond Nuclear.

2. I live at 471 Kirks Mill Road, Nottingham, PA 19362.

My home is located within the 10-mile radiological Emergency Planning Zone (EPZ) of the Peach Bottom Atomic Power Station Units 2 and 3, for which Exelon Generation Company, LLC has applied to the United States Nuclear Regulatory Commission ("NRC") for a second license renewal of its operating license. The NRC has previously renewed the operating license for Peach Bottom Atomic Power Station Units 2 and 3 for an additional 20-years beyond the original 40-year license which will now expire in 2033 and 2034, respectively. If the NRC grants Exelon's Subsequent License Renewal (SLR) Application, the second relicensing dates will expire in 2053 and 2054.

3. Based on the historical experience of nuclear power plants, I believe that these facilities are inherently dangerous. Continued operation of Peach Bottom Units 2 and 3 for an additional twenty-years beyond 2033 and 2034 could cause a severe nuclear accident in the reactor(s) and/or irradiated fuel storage pond(s), thereby causing death, injury, illness, dislocation and economic damage to me and my family. It could also cause devastating environmental damage.

4. I believe Exelon's SLR Application for Peach Bottom Units 2 and 3 is inadequate to reasonably ensure the protection of my health, safety and the environment. Therefore, I have authorized Beyond Nuclear to represent my interests in this proceeding.

Ernest Eric Guyll
(SIGNATURE)

10/20/18
(DATE)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

IN THE MATTER OF EXELON GENERATION COMPANY, LLC PEACH BOTTOM UNITS 2 & 3	)))))	DOCKETS 50-000277 & 50-000278 SLR

DECLARATION OF JOHN S. ADAMS

Under penalty of perjury, John S. Adams declares as follows:

1. My name is John S. Adams. I am a member of Beyond Nuclear.

2. I live at 1464 Silver Spring Rd., Drumore, PA 17518.

My home is located within the 10-mile radiological Emergency Planning Zone (EPZ) of the Peach Bottom Atomic Power Station Units 2 and 3, for which Exelon Generation Company, LLC has applied to the United States Nuclear Regulatory Commission ("NRC") for a second license renewal of its operating license. The NRC has previously renewed the operating license for Peach Bottom Atomic Power Station Units 2 and 3 for an additional 20-years beyond the original 40-year license which will now expire in 2033 and 2034, respectively. If the NRC grants Exelon's Subsequent License Renewal (SLR) Application, the second relicensing dates will expire in 2053 and 2054.

3. Based on the historical experience of nuclear power plants, I believe that these facilities are inherently dangerous. Continued operation of Peach Bottom Units 2 and 3 for an additional twenty-years beyond 2033 and 2034 could cause a severe nuclear accident in the reactor(s) and/or irradiated fuel storage pond(s), thereby causing death, injury, illness, dislocation and economic damage to me and my family. It could also cause devastating environmental damage.

4. I believe Exelon's SLR Application for Peach Bottom Units 2 and 3 is inadequate to reasonably ensure the protection of my health, safety and the environment. Therefore, I have authorized Beyond Nuclear to represent my interests in this proceeding.

John S. Adams

(SIGNATURE)

10-29-2018

(DATE)

Attachment 3

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

IN THE MATTER OF EXELON GENERATION COMPANY, LLC PEACH BOTTOM UNITS 2 & 3	)	DOCKETS 50-000277 & 50-000278 SLR

DECLARATION OF VIRGINA TOPKIS

Under penalty of perjury, Virginia Topkis declares as follows:

1. My name is Virginia Topkis. I am a member of Beyond Nuclear.

2. I live at 180 Honeysuckle Rd., Nottingham, PA 19362.

My home is located within the 10-mile radiological Emergency Planning Zone (EPZ) of the Peach Bottom Atomic Power Station Units 2 and 3, for which Exelon Generation Company, LLC has applied to the United States Nuclear Regulatory Commission ("NRC") for a second license renewal of its operating license. The NRC has previously renewed the operating license for Peach Bottom Atomic Power Station Units 2 and 3 for an additional 20-years beyond the original 40-year license which will now expire in 2033 and 2034, respectively. If the NRC grants Exelon's Subsequent License Renewal (SLR) Application, the second relicensing dates will expire in 2053 and 2054.

3. Based on the historical experience of nuclear power plants, I believe that these facilities are inherently dangerous. Continued operation of Peach Bottom Units 2 and 3 for an additional twenty-years beyond 2033 and 2034 could cause a severe nuclear accident in the reactor(s) and/or irradiated fuel storage pond(s), thereby causing death, injury, illness, dislocation and economic damage to me and my family. It could also cause devastating environmental damage.

4. I believe Exelon's SLR Application for Peach Bottom Units 2 and 3 is inadequate to reasonably ensure the protection of my health, safety and the environment. Therefore, I have authorized Beyond Nuclear to represent my interests in this proceeding.

Virginia A. Topkis
(SIGNATURE)

Nov. 9, 2018
(DATE)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of Exelon Generation Co., L.L.C. Peach Bottom Atomic Power Station, Units 2 & 3	))))))	Docket Nos. 50-277/278 SLR

DECLARATION OF DAVID A. LOCHBAUM

Under penalty of perjury, I, David A. Lochbaum, declare:

1. My name is David A. Lochbaum. By education and experience, I am an expert on nuclear power safety issues.

2. I have significant expertise in the field of nuclear power plant safety. I have a bachelor of science degree in nuclear engineering and formal certifications as a Shift Technical Advisor and Reactor Technology Instructor. For over 17 years, I worked as in the nuclear industry as a reactor engineer, shift technical advisor, system engineer, and licensing engineer. For nearly 21 years, I was employed by the Union of Concerned Scientists (UCS) monitoring safety levels of nuclear power reactors operating in the United States. My tenure with UCS consisted of two multiple-year periods sandwiched around one year working for the Nuclear Regulatory Commission (NRC) at their Technical Training Center teaching boiling water reactor technology to NRC employees for their initial qualifications as inspectors and reviewers and for their re-qualifications. Recently, I retired from UCS and became an independent consultant. A copy of my curriculum vitae is attached.

3. I am familiar with NRC regulations and guidance regarding nuclear power plant safety, including safety standards and guidance for license renewal and operation during renewed operating license terms. I am also generally familiar with reactor aging mechanisms and their effects, and with government and industry evaluations of those subjects.

4. I have been retained by Beyond Nuclear, Inc., to evaluate the subsequent license renewal application submitted by Exelon Generation Co. L.L.C. to the NRC in July 2018. My expert report on the application, entitled Proposed Subsequent License Renewal of Peach Bottom Units 2 and 3: Exelon's Aging Management Programs Fail to Provide Adequate Measures for Consideration of Operating Experience Throughout the Period of Extended Operation (Nov. 15, 2018), is attached to my declaration. I understand that Beyond Nuclear plans to submit a hearing request and petition to intervene in this proceeding, based on my expert report.

5. The factual statements in my expert report are true and correct to the best of my knowledge, and the opinions stated therein are based on my best professional judgment.

The foregoing statements are true and correct.

David A. Lochbaum

11-16-2018

Date

David A. Lochbaum

EDUCATION

June 1979 Bachelor of Science in Nuclear Engineering, The University of Tennessee at Knoxville

EXPERIENCE SUMMARY

03/10 to 11/18 *Director – Nuclear Safety Project*
Union of Concerned Scientists

Responsible for directing UCS's nuclear safety program, for monitoring developments in the nuclear industry, for serving as the organization's spokesperson on nuclear safety issues, for initiating action to correct safety concerns, for authoring reports and briefs on safety issues, and for presenting findings to the Nuclear Regulatory Commission, the US Congress, and state and local officials. Co-authored with Edwin Lyman and Susan Stranahan the book *Fukushima: The Story of a Nuclear Disaster* published by The New Press.

03/09 to 03/10 *Reactor Technology Instructor*
U.S. Nuclear Regulatory Commission
Technical Training Center

Responsible for providing initial qualification and re-qualification training on boiling water reactor technology for NRC employees. Activities included revising chapters of the training manual, conducting classroom and control room simulator training sessions, maintaining the test question database, administering examinations, and assisting the development of an interactive 3-D model of the reactor pressure vessel and its internals.

10/96 to 02/09 *Director - Nuclear Safety Project*
Union of Concerned Scientists

Responsible for directing UCS's nuclear safety program, for monitoring developments in the nuclear industry, for serving as the organization's spokesperson on nuclear safety issues, for initiating action to correct safety concerns, for authoring reports and briefs on safety issues, and for presenting findings to the Nuclear Regulatory Commission, the US Congress, and state and local officials.

11/87 to 09/96 *Senior Consultant*
Enercon Services, Inc.

Responsible for developing the conceptual design package for the alternate decay heat removal system, for closing out partially implemented modifications, reducing the backlog of engineering items, and providing training on design and licensing bases issues at the Perry Nuclear Power Plant.

Responsible for developing a topical report on the station blackout licensing bases for the Connecticut Yankee plant.

Responsible for vertical slice assessment of the spent fuel pit cooling system and for confirmation of licensing commitment implementation at the Salem Generating Station.

Responsible for developing the primary containment isolation devices design basis document, reviewing the emergency diesel generators design basis document, resolving design document open items, and updating design basis documents for the FitzPatrick Nuclear Power Plant.

Responsible for the design review of balance of plant systems and generating engineering calculations to support the Power Uprate Program for the Susquehanna Steam Electric Station.

Responsible for developing the reactor engineer training program, revising reactor engineering technical and surveillance procedures and providing power maneuvering recommendations at the Hope Creek Generating Station.

Responsible for supporting the lead BWR/6 Technical Specification Improvement Program and preparing licensing submittals for the Grand Gulf Nuclear Station.

03/87 to 08/87 *System Engineer*
General Technical Services

Responsible for reviewing the design of the condensate, feedwater and raw service systems for safe shutdown and restart capabilities at the Browns Ferry Nuclear Plant.

08/83 to 02/87 *Senior Engineer*
Enercon Services, Inc.

Responsible for performing startup and surveillance testing, developing core monitoring software, developing the reactor engineer training program, and supervising the reactor engineers and Shift Technical Advisors at the Grand Gulf Nuclear Station.

10/81 to 08/83 *Reactor Engineer / Shift Technical Advisor*
Tennessee Valley Authority
Browns Ferry Nuclear Plant

Responsible for performing core management functions, administering the nuclear engineer training program, maintaining ASME Section XI program for the core spray and control rod drive systems, and covering STA shifts at the Browns Ferry Nuclear Plant.

06/81 to 10/81 *BWR Instructor*
General Electric Company
BWR/6 Training Center

Responsible for developing administrative procedures for the Independent Safety Engineering Group (ISEG) at the Grand Gulf Nuclear Station.

01/80 to 06/81 *Reactor Engineer / Shift Technical Advisor*
Tennessee Valley Authority
Browns Ferry Nuclear Plant

Responsible for directing refueling floor activities, performing core management functions, maintaining ASME Section XI program for the RHR system, providing power maneuvering recommendations and covering STA shifts at the Browns Ferry Nuclear Plant.

06/79 to 12/79 *Junior Engineer*
Georgia Power Company
Edwin I. Hatch Nuclear Plant

Responsible for completing pre-operational testing of the radwaste solidification systems and developing design change packages for modifications to the liquid radwaste systems at the Edwin I. Hatch Nuclear Plant. Also qualified as a station nuclear engineer and covered shifts during startups, control rod pattern exchanges, and other power maneuvers.

OTHER QUALIFICATIONS

January 2010 Certified as a boiling water reactor technology instructor at the U.S. Nuclear Regulatory Commission

April 1982 Certified as a Shift Technical Advisor at the TVA Browns Ferry Nuclear Plant

May 1980 Certified as an Interim Shift Technical Advisor at the TVA Browns Ferry Nuclear Plant

Member, American Nuclear Society (since 1978).

PUBLICATIONS (ABRIDGED LIST)

<u>Books</u>

Fukushima: The Story of a Nuclear Disaster. Co-authored with Edwin Lyman and Susan Q. Stranahan. 2014. The New Press. New York, NY

Nuclear Waste Disposal Crisis. 1996. PennWell Book. Tulsa, OK.

<u>Reports</u>

The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions. Co-authored with Steve Clemmer, Jeremy Richardson, and Sandra Sattler. 2018. Union of Concerned Scientists. Cambridge, MA.

The Nuclear Regulatory Commission and Safety Culture: Do As I Say, Not As I Do. February 2017. Union of Concerned Scientists. Cambridge, MA.

Near Misses at U.S. Nuclear Power Plants in 2015. March 2016. Union of Concerned Scientists. Cambridge, MA.

The NRC and Nuclear Power Plant Safety in 2014: Tarnished Gold Standard. March 2015. Union of Concerned Scientists. Cambridge, MA.

The NRC and Nuclear Power Plant Safety in 2013: More Jekyll, Less Hyde. March 2014. Union of Concerned Scientists. Cambridge, MA.

The NRC and Nuclear Power Safety in 2012: Tolerating the Intolerable. March 2013. Union of Concerned Scientists. Cambridge, MA.

The NRC and Nuclear Power Safety in 2011: Living on Borrowed Time. March 2012. Union of Concerned Scientists. Cambridge, MA.

The NRC and Nuclear Power Plant Safety in 2010: A Brighter Spotlight Needed. March 2011. Union of Concerned Scientists. Cambridge, MA.

Regulatory Roulette: The NRC's Inconsistent Oversight of Radioactive Releases from Nuclear Power Plants. September 2010. Union of Concerned Scientists. Cambridge, MA.

Fire When Not Ready. Co-authored with Paul Gunter and Jim Warren. Beyond Nuclear, Takoma Park, MD. NC WARN, Durham, NC. Union of Concerned Scientists. Cambridge, MA.

Nuclear Power in a Warming World: Assessing the Risks, Addressing the Challenges. Co-authored with Lisbeth Gronlund and Edwin Lyman. December 2007. Union of Concerned Scientists. Cambridge, MA.

Walking a Nuclear Tightrope: Unlearned Lessons of Year-plus Reactor Outages. September 2006. Union of Concerned Scientists. Cambridge, MA.

U.S. Nuclear Plants in the 21st Century: The Risk of a Lifetime. May 2004. Union of Concerned Scientists. Cambridge, MA.

Davis-Besse: One Year Later. March 2003. Union of Concerned Scientists. Cambridge, MA.

Anatomy of a Flawed Decision: NRC Has a Brain, Bui No Spine. Co-authored with Paul Gunter. August 2002. Nuclear Information and Resource Service, Takoma Park. Union of Concerned Scientists. Cambridge, MA.

Nuclear Plant Risk Studies: Failing the Grade. August 2000. Union of Concerned Scientists. Cambridge, MA.

The Good, The Bad, and the Ugly: A Report on Safety in America's Nuclear Power Industry. June 1998. Union of Concerned Scientists. Cambridge, MA.

Potential Nuclear Safety Hazard: Reactor Operation with Failed Fuel Cladding. April 1998. Union of Concerned Scientists. Cambridge, MA.

Blogs

Yankee Rowe and Reactor Vessel Safety. July 19, 2018. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Nuclear Bathtub Safety. September 13, 2016. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Kudos to Cuomo: New York Helps Prevent Degraded Bolts from Leading to Nuclear Disaster. April 7, 2016. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Indian Point's Baffling Bolts. March 31, 2016. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Duane Arnold: The Safety Upgrade that Downgraded Safety. December 2, 2015. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

The Bathtub Curve, Nuclear Safety, and Run-to-Failure. November 17, 2015. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Nuclear Plant Lifetimes. September 8, 2015. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

New, Renewed, and Subsequent Nuclear Reactor Risks. July 21, 2015. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Nuclear Autopsies. July 14, 2015. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

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Exelon's Full Fixes. August 12, 2014. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Fission Stories #148: FitzPatrick—When Being the Best Isn't Good Enough. October 15, 2013. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Cracked Steam Generator Tubes at San Onofre. March 27, 2012. Union of Concerned Scientists. All Things Nuclear blog https://allthingsnuclear.org.

Proposed Subsequent License Renewal of Peach Bottom Units 2 and 3: Exelon's Aging Management Programs Fail to Provide Adequate Measures for Consideration of Operating Experience Throughout the Period of Extended Operation

A Report by David A. Lochbaum
Prepared for Beyond Nuclear, Inc.

November 16, 2018

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Executive Summary

The license renewal rule requires effective aging management of applicable structures, systems, and components throughout the period of extended operating. Operating experience is an integral part of effective aging management, both in establishing adequate programs and in revising the programs when necessary to maintain their effectiveness. Abundant evidence speaks to the vital role played by operating experience in shaping, and re-shaping, aging management programs for operation of reactors during license renewal terms.

Abundant evidence also speaks to gaps, deficiencies, and uncertainties in present understanding of aging degradation mechanisms. The NRC staff has identified several key systems and components as posing "*the most significant technical issues challenging operation beyond 60 years*" — reactor pressure vessel embrittlement, irradiation-assisted stress corrosion cracking of reactor internals, concrete and containment degradation, and electrical cable qualification and condition assessment (NRC 2014c, Enclosure 1, page 3). As stated by the NRC, "*it is the industry's responsibility to resolve these and other issues to provide the technical bases to ensure safety operation beyond 60 years*" (*Id*.).

Feedback from operating experience is needed to close the knowledge gaps regarding these key systems and components. Learning from operating experience is key to enabling the changes that will ensure the effectiveness of aging management programs throughout reactor operating lifetimes that could be double the initial 40-year license term.

Several reactors have closed in recent years, closures of several other reactors have already been announced, other reactors could cease operating before either Peach Bottom reactor enters the subsequent license renewal period, and still other reactors could shut down during the period of extended operation. Consequently, the amount of available reactor operating experience could be significantly reduced.

The subsequent license renewal application submitted by Exelon Generation Co., L.L.C. (Exelon) for Peach Bottom Units 2 and 3 describes how operating experience was factored into its aging management programs. But the application fails to acknowledge how dependent the aging management programs are on internal and external operating experience sources. And it fails to address the degree to which the closure of reactors and the associated reduction in the amount of external operating experience may impair the effectiveness of its aging management programs. Finally, the application fails to show how Exelon can obtain information about operating experience from alternate sources should closure of reactors eliminate that option. Thus, the application fails to comply with the regulatory requirement to identify how aging of applicable structures, systems, and components will be adequately managed throughout the period of extended operation. Therefore, the operating licenses for Peach Bottom Units 2 and 3 is inadequate to satisfy the license renewal requirements.

In order to ensure compliance with NRC license renewal regulations and provide adequate protection of public health and safety, Exelon's subsequent license renewal application must describe three factors:

(a) The degree to which Exelon's aging management programs depend on external operating experience,

(b) How Exelon will determine what amount of operating experience information is sufficient to ensure effectiveness of the programs, and

(c) How operating experience will be augmented if it is deemed insufficient.

Exelon's license for Peach Bottom Units 2 and 3 should not be renewed until these actions have been taken.

1.0 Background: Initial Nuclear Power Reactor Licensing and License Renewal

At the time of initial licensing of a nuclear power reactor, Nuclear Regulatory Commission (NRC) regulations required a demonstration that the reactor's structures, systems and components will remain functional under conditions experienced during routine operation and anticipated accidents. Specifically, Specifically, 10 CFR 50.40 requires that throughout the operating license term, the facility and equipment must provide reasonable assurance that public health and safety will not be endangered. And General Design Criterion 4 (GDC-4) in Appendix A to 10 CFR Part 50 requires that:

> *Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.* (NRC 2007)

Conformance of the Peach Bottom Unit 2 and 3 reactors with GDC-4 is described in Appendix H of the Updated Final Safety Analysis Report (UFSAR) (PBAPS 2017a).[1] Appendix H describes how applicants for construction permits were required by 10 CFR 50.34 to describe principle design criteria for the facility and how conforming with the General Design Criteria of 10 CFR 50 Appendix A was a way to satisfy that requirement (PBAPS 2017a, page H.1-2).

The Atomic Energy Commission (AEC, NRC's predecessor) issued 40-year reactor operating licenses for Peach Bottom Units 2 and 3 on October 25, 1973 and July 2, 1974, respectively (NRC 2018a, page 104). On August 25, 2014, the NRC issued amendments to the reactor operating licenses for Peach Bottom Units 2 and 3 approving an increase in the maximum thermal power level from 3,514 megawatts thermal to 3,951 megawatts thermal (NRC 2014d, page 1). The NRC considered the increase to be an Extended Power Uprate (EPU).

UFSAR Section H.3 describes how the EPU did not undermine conformance with Appendix A to 10 CFR Part 50. Conformance with GDC-4 is explicitly discussed in UFSAR Sections H.3.2.6, H.3.7.1, H.3.7.3, and H.3.8.6.2. (PBAPS 2017a, pages H.3-8, H.3-26, H.3-27, and H.3-41) The discussion of the potential EPU impacts in the Peach Bottom UFSAR illustrates that conformance with GDC-4 is a requirement throughout the reactor operating lifetime rather than merely a prerequisite for initial reactor licensing.

Regardless of how well a nuclear reactor is operated, over time the stresses of radiation, temperature, and humidity take a toll on structures, systems, and components. Effects of these stresses include pipe wall thinning from erosion and corrosion, metal embrittlement, and degradation of concrete due to chemical reactions with groundwater. The environmental conditions during routine reactor operation, transients, and accidents affect structures and components in different ways. Prolonged exposure to elevated temperature during sustained operation at rated power causes electrical cable insulation to deteriorate. Planned, controlled startups and shutdowns of the reactor result in stresses on components as temperature increases and decreases cause expansions and contractions. Rapid temperature changes during transients and accidents accelerate such wear and tear effects. Conformance with GDC-4 protects safety margins from being compromised from the effects of environmental conditions.

[1] The General Design Criteria (GDC) were being develop in parallel with the construction and licensing of Peach Bottom. UFSAR Appendix H discusses conformance with the draft GDC and the final GDC. During development, some of the draft GDC were revised and/or renumbered. Draft GDC-4 dealt with sharing of safety systems at plants with multiple reactors. Final GDC-4 deals with environmental conditions. For this report (as in the cited UFSAR sections), GDC-4 refers to the final version.

Federal regulations permit reactor operating licenses to be renewed for up to 20 years if the NRC determines that actions have been taken or will be taken to manage the effects of aging of applicable systems, structures, and components during the period of extended operation and time-limited aging analyses have been identified (10 CFR 54.29). Applications for license renewal must contain an Aging Management Plan identifying the items subject to aging management and describing how the effects of aging will be adequately managed so that the intended functions will be maintained during the period of extended operation (10 CFR 54.21). [2]

Researchers at the Pacific Northwest National Laboratory described the role of aging management programs in maintaining nuclear safety margins:

> *Understanding the causes and control of degradation mechanisms forms the basis for developing aging management programs (AMPs) to ensure the continued functionality of and maintenance of safety margins for NPP SSCs [structures, systems, and components]. The AMPs, along with the appropriate technical basis, are used to demonstrate reasonable assurance of safe operation of the SSCs during the SLR* [subsequent license renewal] *period.* (Ramuhali 2017, page 1)

Effective aging management programs therefore serve to assure conformance with GDC-4 throughout the period of extended operation, not just at the time of license renewal.

[2] While NRC regulations refer to a single Aging Management Plan, in fact multiple programs are used to manage aging. For example, one program handles concrete degradation while a separate program monitors electrical cables. These various programs rely on different sources of operating experience – some from internal sources (e.g., results of tests and inspections at Peach Bottom) and some from external sources (e.g., results from other plants).

2.0 Operating Experience – An Essential Element of Effective Aging Management Programs

The NRC has long recognized the vital role played by operating experience (OpE) in assuring safe operation of nuclear plants. Operating experience identifies both best practices to emulate and bad outcomes to avoid.

The NRC significantly expanded its Operating Experience Program in the late 1970s after discovering that a precursor to the accident at the Three Mile Island nuclear plant in Pennsylvania had occurred less than two years earlier at the Davis-Besse plant in Ohio.[3] At Davis-Besse in September 1977, when a valve failed to properly re-close, the operators avoided an accident by recognizing a set of conflicting indicators and responding appropriately. The event was reported to the NRC, but this information was not widely shared with other plant owners. Had the Three Mile Island operators been aware of the Davis-Besse experience, they might have learned from it and avoided the partial meltdown of the Unit 2 reactor in March 1979 (NRC 1980a and NRC 1980b).

Internal sources of operating experience include results from tests and inspections and reports generated by the plant's quality assurance program. External sources of operating experience include advisories from vendors, generic correspondence sent by the NRC to plant owners, and information disseminated by the Institute for Nuclear Power Operations.

Plant owners are required to evaluate operating experience and take actions when applicable. For example, 10 CFR 50 Appendix B requires 18 quality assurance measures to be taken to identify safety problems and implement effective corrective actions in a timely and effective manner. Safety problems are often identified by plant owners during their review of operating experience reports. The NRC routinely evaluates the scope and effectiveness of operating experience review programs during Problem Identification and Resolution (PI&R) inspections. NRC's inspectors are explicitly tasked with evaluating whether "*Operating experience is adequately evaluated for applicability, and applicable lessons learned are communicated to appropriate organizations and implemented*" (NRC 2015a, page 15).

The NRC also requires consideration of operating experience in the context of license renewal. Operating experience during the initial license term must be considered in a license renewal application; and ongoing consideration of operating experience must be included in an applicant's aging management plan.

In order to "*ensure that substantial operating experience is accumulated*" before a reactor license is renewed, the NRC forbids nuclear plant owners from applying for license renewal more than 20 years before the expiration of the current reactor operating license (10 CFR 54.17). As the NRC explained in the Statements of Consideration accompanying the license renewal rule:

> *Neither the AEA* [Atomic Energy Act as amended] *nor the Commission's current regulations set a limit on how long before expiration of the operating license a renewal application may be filed.* ***The Commission has decided to impose such a limit to ensure that substantial operating experience is accumulated*** *by a licensee before it submits a renewal application.* (NRC 1991, page 54-SC-21; 56 FR 64943) (emphasis added)

[3] Information Notices issued by the NRC (see https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/) are but one example of the agency's expanded Operating Experience Program.

Thus, the NRC recognized that it was not enough to have considered operating experience when crafting aging management programs for license renewal — it was necessary to have a *sufficient amount* of operating experience to adequately inform decisions about aging management programs. An application for license renewal submitted more than 20 years before the expiration of the current license might be based on insufficient operating experience to adequately inform decisions about effective aging management programs.

The Statements of Consideration for the license renewal rule also described the continuing role played by operating experience in maintaining safety after operating licenses are renewed:

> *Since initial licensing, each operating plant has continually been inspected and reviewed as a result of new information gained from operating experience. Ongoing regulatory processes provide reasonable assurance that, as new issues and concerns arise, measures needed to ensure that operation is not inimical to the public health and safety and common defense and security are "backfitted" onto the plants.* (NRC 1991, 56 FR at page 64945)
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> * * *
>
> *The NRC receives information on operating events from licensees in the form of licensee event reports and disseminates information that may be relevant to safety, safeguards, or environmental issues in the form of information notices. The NRC also transmits information to and requests action by licensees through bulletins and other reports such as generic letters. ... The total program offers a high degree of assurance that events that are potentially risk significant or precursors to potentially significant events are being reviewed and resolved expeditiously.* (NRC 1991, 56 FR at page 64947)
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> * * *
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> ***The CLB* [current licensing basis] *of a plant will continue to evolve throughout the term of the renewed license to address the effects of age-related degradation as well as any other operational concern that arises. The licensee must continue to ensure that the plant is being operated safely and in conformance with its licensing basis. The NRC's regulatory oversight activities will also assess any new information on age-related degradation or plant operation issues and take whatever regulatory action is appropriate for ensuring the protection of the public health and safety.*** (NRC 1991, 56 FR at page 64943) (emphasis added)

Operating experience essentially confirms the appropriateness of existing regulatory requirements and industry practices or identifies shortcomings that are remedied. In other words, measures needed to ensure safety during reactor operation are not frozen in time when the initial operating license or renewed operating license is issued. Instead, the measures needed to ensure reactor safety are fluid and dynamic, changing when appropriate in response to operating experience.

Since issuance of Final License Renewal Interim Staff Guidance LR-ISG-2011-05 in March 2012, the NRC has mandated that reactor operating license renewal applications must expressly describe how operating experience will be used on an ongoing basis:

> ***Consideration of future plant-specific and industry operating experience relating to aging management programs should be discussed.*** *Reviews of operating experience by the applicant in the future may identify areas where aging management programs should be enhanced or new programs developed.* ***An applicant should commit to a future review of plant-specific and industry operating experience to confirm the effectiveness of its aging management programs***

> ***or indicate a need to develop new aging management programs.*** *This information should provide objective evidence to support the conclusion that the effects of aging will be managed adequately so that the structure and component intended function(s) will be maintained during the period of extended operation.* (NRC 2012, page 1) (emphasis added)
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> * * *
>
> ***The summary description of the programs and activities for managing the effects of aging for the period of extended operation in the FSAR Supplement should be sufficiently comprehensive, such that later changes can be controlled by 10 CFR 50.59. The description should contain information associated with the bases for determining that aging effects will be managed during the period of extended operation.*** *The description should also contain any future aging management activities, including enhancements and commitments, to be completed before the period of extended operation.* (NRC 2012, page 2) (emphasis added)
>
> * * *
>
> ***The nature of operating experience is such that it can come from a variety of sources and may affect any number of areas of plant operation. Thus, potentially relevant operating experience must be screened and, if necessary, further reviewed to determine whether any subsequent actions should be taken****. ... In this regard, the NRC staff believes that guidance on the ongoing review of operating experience for license renewal should primarily be addressed under generic processes used to inform each AMP and, when necessary, to develop and implement new AMPs.* (NRC 2012, page 4) (emphasis added)

In July 2017, the NRC incorporated its 2012 mandate into revisions to its Generic Aging Lessons Learned report (GALL-SLR) and Standard Review Plan for Subsequent License Renewal (SRP-SLR). Appendix B to the GALL-SLR is devoted to the use of ongoing operating experience in managing the effect of aging during the period of extended operation:

> *Operating experience (OE) is a crucial element of an effective aging management program (AMP).* ***It provides the basis to support all other elements of the AMP and, as a continuous feedback mechanism, drives changes to these elements to maintain the overall effectiveness of the AMP.*** *OE should provide objective evidence to support the conclusion that the effects of aging are managed adequately so that the structure- and component-intended function(s) will be maintained during the subsequent period of extended operation.* (NRC 2017a, page B-1) (emphasis added)
>
> ***The systematic review of plant-specific and industry OE concerning aging management and age-related degradation confirms that the subsequent license renewal (SLR) AMPs are, and will continue to be, effective in managing the aging effects for which they are credited. The AMPs should either be enhanced or new AMPs developed, as appropriate, when it is determined through the evaluation of OE that the effects of aging may not be adequately managed. AMPs should be informed by the review of OE on an ongoing basis, regardless of the AMP's implementation schedule.*** (NRC 2017a, page B-1) (emphasis added)

Appendix A.4 to the SRP-SLR is devoted to using operating experience in managing the effect of aging during the period of extended operation requiring licensees to identify any corrective actions in appropriate updates to quality assurance programs maintained under 10 CFR Part 50, Appendix B:

The systematic review of plant-specific and industry OE, including relevant research and development concerning aging management and age-related degradation ensures that the SLR AMPs are, and will continue to be, effective in managing the aging effects for which they are credited. The AMPs should either be enhanced or new AMPs developed, as appropriate, when it is determined through the evaluation of OE that the effects of aging may not be adequately managed. AMPs should be informed by the review of OE on an ongoing basis, regardless of the AMP's implementation schedule. (NRC 2017b, page A.4-1) (emphasis added)

* * *

A means should be established within the corrective action program to identify, track, and trend OE that specifically involves age-related degradation. There should also be a process to identify adverse trends and to enter them into the corrective action program for evaluation. (NRC 2017b, page A.4-2) (emphasis added)

* * *

Operating experience, including relevant research and development items identified as potentially involving aging, should receive further evaluation. This evaluation should specifically take into account the following: (a) systems, structures, and components, (b) materials, (c) environments, (d) aging effects, (e) aging mechanisms, (f) AMPs, and (g) the activities, criteria, and evaluations integral to the elements of the AMPs. The assessment of this information should be recorded with the OE evaluation. ***If it is found through evaluation that any effects of aging may not be adequately managed, then a corrective action should be entered into the 10 CFR Part 50, Appendix B, program to either enhance the AMPs or develop and implement new AMPs.*** (NRC 2017b, page A.4-2) (emphasis added)

* * *

Assessments should be conducted on the effectiveness of the AMPs and activities. These assessments should be conducted on a periodic basis that is not to exceed once every 5 years. They should be conducted regardless of whether the acceptance criteria of the particular AMPs have been met. (NRC 2017b, page A.4-2)

Sections of the SRP-SLR specify how operating experience is to be considered on an ongoing basis to sustain effective aging management programs. For example, Section 3.2.3.2.6 states:

The applicant's AMPs should contain the element of OE. ***The reviewer verifies that the applicant has appropriate programs or processes for the ongoing review of both plant-specific and industry OE concerning age-related degradation and aging management. Such reviews are used to ensure that the AMPs are effective to manage the aging effects for which they are created. The AMPs are either enhanced or new AMPs are developed, as appropriate, when it is determined through the evaluation of OE that the effects of aging may not be adequately managed.*** (NRC 2017b, page 3.2-13) (emphasis added)

In addition, the procedures used by the NRC when conducting inspections prior to license renewal and after license renewal explicitly provide for assessment by the NRC of the applicant's use of operating experience:

It is recommended that a system be selected to perform a vertical slice review in order to determine if the applicant properly accounted for all possible environmental aging effects on that

> *system in the LRA* [license renewal application]. *The purpose of this selection is to assess for a single system whether the applicant properly identified operating experience, including historical site experience, regarding the effects of aging on the system and placed the system, structures and components for the selected system into an established aging management program.* (NRC 2011, pages 2-3)
>
> * * *
>
> *In selecting samples, consideration should be given to attributes such as … whether the licensee has updated its AMPs as a result of recent operating experience since the issuance of its renewed license.* (NRC 2016, page 4)

In overseeing the operation of individual reactors, the NRC has also audited the effectiveness of the aging management programs in considering operating experience. For example, following a license renewal-related audit of Nine Mile Point Unit 1 (NMP-1), the NRC reported:

> *The NMP-1 audit found that the licensee performs a quarterly health report that includes a review of the related industry operating experience (OpE) and incorporates the findings into its inspection plans, which is potentially important for an ISI* [in-service inspection] *program based mainly on a consensus set of ASME code requirements. The risk-informed part of the ISI program at NMP-1 also requires a review of OpE.* (Chopra 2013, page 10)

In reviewing the license renewal application for River Bend, the NRC staff questioned how operating experience about aging effects would be evaluated (NRC 2018d, page 8). The owner responded to the NRC (Maguire 2018, Enclosure 1 pages 18-20):

> *In accordance with these programs, site-specific and industry operating experience items are screened to determine whether they involve lessons learned that may impact aging management programs (AMPs). Items are evaluated, and affected AMPs are either enhanced or new AMPs are developed, as appropriate, when it is determined that the effects of aging are not adequately managed. Plant-specific operating experience associated with managing the effects of aging is reported to the industry in accordance with guidelines established in the operating experience review program.*
>
> * * *
>
> *The results of implementing aging management programs (e.g., data from inspections, tests, analyses) are evaluated to determine whether the effects of aging are adequately managed. These evaluations are conducted regardless of whether the acceptance criteria of the particular AMP have been met. A determination is made as to whether the frequency of future inspections should be adjusted, whether new inspections should be established, and whether the inspection scope should be adjusted. If the effects of aging are not being adequately managed, then a corrective action is entered into the 10 CFR Part 50, Appendix B, program to either enhance the AMP or develop and implement new aging management activities.*

The NRC's audit at Nine Mile Point and request for additional information from River Bend reflect the agency's expectation that effective aging management programs include the review of operating experience and, when appropriate, trigger revisions when needed to maintain the effectiveness of the programs. As discussed above, the SRP-SLR explicitly requires:

> *A means should be established within the corrective action program to identify, track, and trend OE that specifically involves age-related degradation. There should also be a process to identify adverse trends and to enter them into the corrective action program for evaluation.* (NRC 2017b, page A.4-2)

Unfortunately, however, the industry guidance documents on aging management and specified in the subsequent license renewal application for Peach Bottom lack quantitative or qualitative criteria for determining the amount of operating experience necessary to adequately inform decisions about the efficacy of aging management programs on an ongoing basis. These criteria would enable licensees, and NRC inspectors, to assess whether the permanent closure of N reactors constitutes an adverse trend warranting evaluation within the corrective action program. Effectively, they would be a post-license-renewal corollary to the criterion on the front-end requiring at least two decades' worth of operating experience to be available before the initial license renewal application can be submitted to the NRC.

The license renewal rule requires effective aging management programs to be maintained throughout the period of extended operation. The SRP-SLR describes how ongoing assessments of operating experience are necessary to ensure effective aging management programs are maintained. But the subsequent license renewal application for Peach Bottom and/or the industry programs it relies upon should explain how Exelon will determine whether sufficient operating experience information remains available for the ongoing assessments to ensure aging management effectiveness is maintained. Explicit description of operating experience information sufficiency is needed in the subsequent license renewal application to enable plant workers and NRC inspectors/reviewers to properly gauge whether a condition adverse to quality under Appendix B to 10 CFR 50 results from permanent reactor closures.

3.0 Operating Experience Has Changed Aging Management Programs

Inspection and testing of structures, systems, and components provides invaluable operating experience. These inspections and tests reveal degradation of materials and operational mistakes before they compromise defense-in-depth safety margins. The operating experience from the inspections and tests drive changes to procurement of replacement parts, training of workers, development of procedures, and other measures intended to ensure that adequate safety margins are maintained.

Operating experience has changed aging management programs. The NRC initially issued its Generic Aging Lessons Learned (GALL) report in July 2001. The NRC described the report:

> *The Generic Aging Lessons Learned (GALL) report contains the staff's generic evaluation of the existing plant programs and documents the technical basis for determining where existing programs are adequate without modification and where existing programs should be augmented for the extended period of operation.* (NRC 2001b, page iii)

The 2001 GALL Report listed aging degradation mechanisms for applicable systems, structures, and components along with methods acceptable to the NRC for managing the aging effects. Owners seeking operating reactor license renewals could specify conformance with the GALL report's methods in their applications or describe alternate methods for the NRC to review and approve if found acceptable.

The NRC revised its GALL Report in 2005. The NRC explained that several changes resulted from operating experience. For example:

> *The NRC Office of Research provided a listing of Licensee Event Reports (LERs) related to failures, cracking, degradation, etc. of passive components. This listing consisted of 128 items. These results were reviewed by the NRC Staff. The Staff subsequently modified AMR line-item R-68 and added AMR line-item RP-22 (on the basis of LER 528-1992-001). R-68 was modified to emphasize stress corrosion cracking associated with nozzle safe end welds. AMR line-item RP-22 was added to identify primary water stress corrosion cracking (PWSCC) of the pressurizer steam space nozzles.* (NRC 2005, page 3)

* * *

> *Operating experience, as discussed in NUREG-1760, "Aging Assessment of Safety-Related Fuses Used in Low and Medium-Voltage Applications in Nuclear Power Plants," indicates that aging stressors such as vibration, thermal cycling, electrical transients, mechanical stress, fatigue, corrosion, chemical contamination, or oxidation of the connection surfaces can result in fuse holder failure. AMP XI.E5 was developed to provide for proper management of the aging effects for this MEAP combination.* (NRC 2005, page 96)

* * *

> *This row* [Item E-42] *is identical to A-01 and was added to cover buried piping in ESF systems. Underground steel (with or without coating or wrapping) piping, piping components, and piping elements exposed to a soil environment are subject to loss of material due to general, pitting, crevice, and microbiologically influenced corrosion.* (NRC 2005, pages 199-200)

* * *

> *Element 1 "Scope of Program" was significantly changed to better address BWRVIP* [Boiling Water Reactor Vessel and Internals Project] *guidance for top guide components. Relevant operating experience of cracking in top guide components was reported at the Oyster Creek, Cooper, and Quad Cities, Unit 1 nuclear plants in the early to mid 1990s. Recent operating experience with cracking in U.S. top guides has been reported as a result of augmented examinations that were conducted at the Nine Mile Point, Unit 1 nuclear plant in 2003 and 2005. Therefore, cracking of U.S. BWR top guides is considered to be relevant operating experience for the U.S BWR fleet and adequate aging management programs for managing cracking of BWR top guides should be proposed for any BWR license renewal application.* (NRC 2005, page 228)

In 2010, the NRC revised the GALL Report again. Once again, the NRC explained that several changes resulted from operating experience. For example:

> *The NRC, Office of Research (RES) provided a listing of Licensee Event Reports (LERs) related to failures, cracking, degradation, etc. of passive components. These results were reviewed by NRC staff. The operating experience elements of numerous AMPs were updated to reflect relevant operating experience identified by the review. In addition, the operating experience review identified a number of examples where vibration-induced fatigue caused cracking of plant components. The staff subsequently modified GALL AMP XI.M35, "One-time Inspection of ASME Code Class 1 Small-bore Piping," to address these concerns.* (NRC 2010, page 3)

The revisions to the GALL Report due to operating experience has changed aging management programs at nuclear plants and resulted in the replacement of components vulnerable to aging degradation. For example, the NRC reported from its audit at HB Robinson (Brady 2014, page 13):

> *Based on the licensee's analysis of the GALL Report, Revision 2, the licensee added (although not credited for license renewal) 480-volt safety related buried cable for the service water pumps, and the diesel generator fuel oil transfer pumps. ... The licensee stated that there are no gaps between HBRSEP's* [HB Robinson Steam Electric Plant's] *cable aging management program for inaccessible power cables and the GALL Report, Revision 2, XI.E3 AMP.*
>
> *The licensee also stated in its industry operating experience evaluation that the underground medium voltage cables (circulating water pumps) are tested every 6 years and the replacement of these cables is scheduled. The licensee also indicated that the low voltage power cable for the service water pumps were replaced and installed in an above ground concrete cable tray.*

The industry has also changed its aging management programs based on operating experience. For example, BWRVIP-26-A, "BWR Top Guide Inspection and Flaw Evaluation Guidelines," was revised in response to the discovery of reactor pressure vessel top guide beam cracking at Oyster Creek (NRC 2015b, page 1).

Feedback from operating experience and appropriate changes to testing, inspection, maintenance, and operating procedures clearly plays an important nuclear safety role. Operating experience has resulted in changes to aging management programs to assure their effectiveness. Absent feedback from operating experience, the effectiveness of aging management programs would deteriorate over time as they become more obsolete and outdated. Reactor safety margins would decline hand-in-hand with the reduced effectiveness of the aging management programs.

As Section 4.0 below describes, it is already known that additional operating experience is needed to sustain the effectiveness of current aging management programs. In other words, today's aging management programs will not remain adequate throughout the period of extended operation. Revisions to aging management programs driven by operating experience feedback are needed to assure safety.

4.0 Aging Management Programs Will Need Further Changes

The industry and NRC have revised aging management programs due to operating experience as described in Section 3.0 above. The aging management programs are more effective than the programs in place 20 years ago. But significant gaps in knowledge about aging and how it affects nuclear plant structures, systems, and components persist. Thus, aging management programs will not remain adequate during the period of extended operation without the refinements and re-calibrations resulting from operating experience feedback. This statement is not overly speculative or subjective — it is based on numerous studies conducted by the Department of Energy and NRC.

It has been reported that knowledge deficiencies about aging degradation mechanisms exist and need to be resolved to maintain the adequacy of aging management efforts. Among the many examples:

> *While all forms of corrosion are important in managing the safe operation of a nuclear reactor, IASCC* [irradiation-assisted stress corrosion cracking] *has received considerable attention over the last four decades due both to its severity and unpredictability.* ***Despite over thirty years of international study, there does not exist a consensus on the underlying mechanism of IASCC, although more recent work in the open literature has identified several possible causes***. (NRC 2014a, page 10) (emphasis added)

Hence, IASCC is known to be an aging problem, but its cause(s) have not yet been definitively and irrefutably identified. Which means, of course, that its solution has also not yet been definitively established.

Degradation of steel components due to thermal aging and irradiation is another example:

> *Due to the potential for thermal aging and fatigue damage during extended lifetimes, the assumptions and limits considered at the design phase for core internal structures should also be examined. During the initial plant design, each component was designed with a load to expected and specific lifetimes and operating conditions using established guidelines (typically those in Section III of the ASME Boiler and Pressure Vessel Code).* ***An 80-year reactor lifetime corresponds to over 600,000 hours of service (at a 90% service factor) while most creep data used in design comes from tests operating much less than 100,000 hours. The extension of lifetimes beyond these initial design considerations should be carefully examined.*** (NRC 2014a, page 11) (emphasis added)
>
> * * *
>
> *Engineering judgments may offer some justification for reactor operation up to 60 years, since that judgment is based largely on the extrapolation of known phenomena after operating lives of 35–40 years.* ***There are concerns, however, regarding the potential degradation of carbon steels and low alloy steels if the operating license was extended a further 20 years to 80 years since this may lead to events associated with time-limiting degradation modes (such as fatigue or thermal aging) and synergisms between different degradation modes (such as irradiation and SCC).*** (NRC 2014b, page 103) (emphasis added)

Results from tests conducted with fewer than 100,000 hours of operation have been extrapolated to predict conditions that may exist more than six times later in operating life. Likewise, data collected after 35 to 40 years of operation has been extrapolated to estimate conditions out to 80 years. A sufficient flow of operating experience as reactors operate longer and longer is required to either confirm these extrapolations or make the mid-term adjustments needed to preserve adequate safety margins.

Concrete degradation is another example:

> ***Irradiation for containment concrete emerged as the most important degradation mechanism, mainly driven by insufficient data to improve the level of knowledge about the effects of irradiation on concrete mechanical properties***. (NRC 2014a, page 24) (emphasis added)
>
> * * *
>
> *The* [expert] *panel also identified the irradiation of concrete as a knowledge gap. This, as mentioned above, is due to a lack of sufficient test data to support a clear evaluation of the significance of such mechanism for long-term operations.* (NRC 2014a, page 26)
>
> * * *
>
> *The effect of gamma radiation on concrete is not well documented. Gamma radiation can cause displacement per atom damage rates comparable to neutrons, but it is generally considered to be less important than neutron exposure.* ***The testing that has been performed to determine an acceptable gamma dose has been generally supportive of the acceptability of concrete, but has been inconclusive****. Additional work is required to document the behavior of concrete exposed to gamma radiation. Levels of gamma exposure that will reduce the compressive strength of concrete should be developed.* (LPI 2013, page 88) (emphasis added)

As in the two examples above, the current state of awareness does not indicate that concrete degradation will be problematic before a reactor operates for 80 years. But it is known that insufficient data is currently available to conclusively show that concrete degradation will not become a problem. Once again, operating experience is needed to either provide the confidence that concrete degradation will not become a problem or identify the aging effects so they can be properly managed.

Electrical cables provide another example:

> ***Little is known regarding the consequences of long-term wetting of both low- and medium-voltage cables***. (NRC 2014a, page 29) (emphasis added)

As with the example of concrete degradation, it is known that electrical cables have been and will continue to be exposed to moisture (e.g., submerged in water when routed in underground conduits) but it is little understood how that environment affects the cables. GDC-4 requires components to withstand the environmental conditions they experience. Not knowing that wetted cables will become impaired is not quite the same as knowing with appropriate confidence levels that the cables can withstand such environmental conditions. Operating experience is needed to supply the information that determines what aging management program provides adequate protection.

Aging management of electrical cables has been reported to be further complicated by the wide range of insulating materials used for the cables as well as limitations in the applicability and reliability of accelerated-aging testing in laboratories:

> *The issues associated with aging of electrical cables are generally complicated by the diversity in materials and formulations that were used in vintage cables. Given the qualification methods used when they were put into service, utilities were able to perform time-limited aging analyses to show with a reasonable assurance that electrical cables would be able to perform their necessary function under a design-basis event through a first round of license extension.* ***However, as***

> ***utilities approach a decision on SLR, there is a general consensus that available data on long-term performance of cables is sparse and in some instances contradictory***. (Rumuhali 2017, page 7) (emphasis added)

* * *

> ***… there is concern that the aging seen in accelerated tests may not always correlate well with field aging. In particular, dose rates and total dose effects, synergistic effects of thermal and radiation aging, and diffusion-limited oxidation are all concerns for the applicability of accelerated aging. Further, there are many instances where the formulations of cable insulation material (polymers) in plants (vintage material) are different from what is available today***. *In these cases, harvested vintage cables can be used for studies to provide the necessary data and plug the knowledge gaps.* (Rumuhali 2017, page 8) (emphasis added)

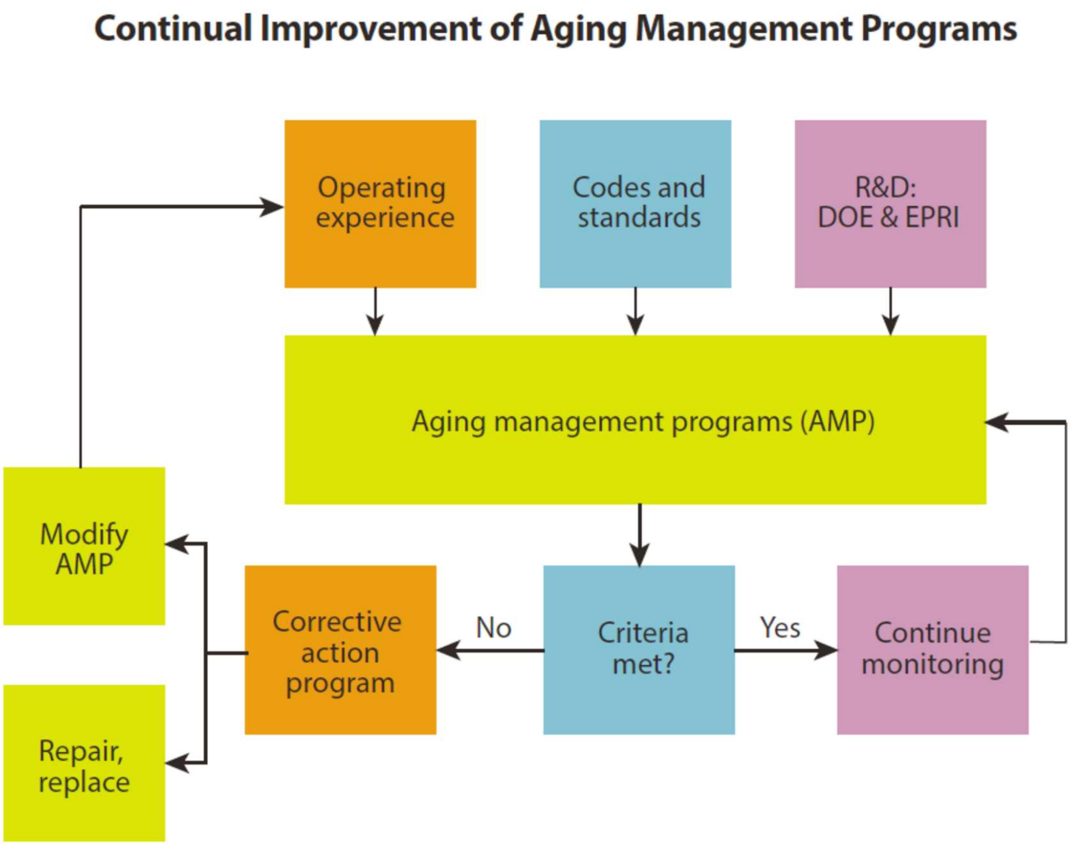
There are nearly 1,000 kilometers (621 miles) of power, control, and instrumentation cables in a typical nuclear power plant and "*… it would be a daunting undertaking to inspect all of the cables*." (Glass 2015, page vii). Because all electrical cables are not inspected for signs of degradation, there must be high confidence in the methods used to estimate whether degradation could impair cables from functioning as needed.

> NOTE: The Pacific Northwest Nuclear Laboratory (PNNL) report (Rumuhali 2017) was downloaded by Paul Gunter of Beyond Nuclear from the web. The report stated that it was "*Prepared for the U.S. Nuclear Regulatory Commission under a Related Services Agreement*." In preparing this report, the NRC's online electronic library was searched for the PNNL document's accession number. When the record could not be found, Mr. Gunter contacted the NRC's Public Document Room (PDR) staff for help. The PDR staff responded that the record was not located in public or non-public ADAMS. Subsequently, the internet was accessed in an attempt to obtain the URL for the PNNL report. As of November 16, 2018, the report was not publicly available in ADAMS and an internet search indicated that the report had been pulled off the web for unspecified reasons.

These deficiencies in the understanding of aging degradation mechanisms need to be resolved to maintain the adequacy of aging management efforts. And their effectiveness is challenged in the context of subsequent license renewal because the longer that reactors operate, the more wear and tear their structures, systems, and components will experience. The knowledge of aging mechanisms is known to be imperfect. Operating experience is needed to fill in the knowledge gaps and trigger any necessary changes to aging management programs.

The nuclear industry's roadmap for subsequent license renewal explicitly acknowledges the continuing role played by operating experience in effective management of aging effects. As shown in Figure 1, operating experience is elemental to the "continual improvement" of aging management programs.

Figure 1



Source: NEI 2015a, page 5

An argument could be made that reactor operating licenses should not be renewed for another 20 years given all the known unknowns. Degradation from irradiation-assisted stress corrosion cracking, concrete irradiation, wetting of low-voltage and medium-voltage electrical cables, and other little understood mechanisms could prevent or impair the intended function of structures and components important to safety — the very outcome the license renewal rule expressly seeks to avoid. Collectively, these known unknowns implicitly mean that today's aging management programs cannot provide adequate protection 20 years from now.

But operating experience feedback counters that argument. The results from inspections and tests shrinks the knowledge gaps while the changes triggered by this feedback enhances the aging management programs. While knowledge deficiencies are known to exist today, operating experience can provide that missing awareness and drive the applicable fixes before it compromises nuclear safety in the future.

The NRC staff essentially made this same point in a policy paper they provided the Commission in 2014 on subsequent license renewal:

> *Based on the information gathered over the past several years, the staff currently believes the most significant technical issues challenging operation beyond 60 years are reactor pressure*

> *vessel embrittlement; irradiation-assisted stress corrosion cracking of reactor internals, concrete structures and containment degradation; and electrical cable qualification and condition assessment. Throughout this process, the staff has emphasized that it is the industry's responsibility to resolve these and other issues to provide the technical bases to ensure safe operation beyond 60 years. The staff will review and provide confirmatory research, as needed, on the sufficiency and completeness of industry's technical data.* .(NRC 2014c Enclosure 1, page 3)

Reactor safety during the period of extended operating therefore depends on sufficient operating experience feedback to ensure that aging management programs receive the changes necessary to maintain their effectiveness.

Figure 1 illustrates the matter. It shows that operating experience is an integral element in the continual improvement of aging management programs. The permanent closure of reactors will reduce the flow of operating experience they currently provide. Absent measures substituting for this lost information from other sources, the Operating Experience box in Figure 1 will get smaller and smaller with each reactor closure. At some point, Operating Experience may become insufficient to maintain effective aging management programs.

The nuclear industry's roadmap for subsequent license renewal recognizes the necessary role that operating experience plays in maintaining the effectiveness of aging management programs during the period of extended operation. But the roadmap implicitly assumes that traffic on that road in the future will be similar to that volume in the past. But as discussed in Section 5.0 below, it is quite possible that fewer and fewer reactors will be traveling along that road thus yielding less and less operating experience feedback.

5.0 Operating Experience Could Be Significantly Reduced

The amount of operating experience available during the SLR terms for Peach Bottom Units 2 and 3 could be significantly reduced in comparison to the amount that was available in the initial license renewal term. The operating licenses for Peach Bottom Units 2 and 3 currently expire on August 8, 2033, and July 2, 2034 respectively (Exelon 2018, page 1-1).

As shown in Table 1, the licenses of more than two dozen of the 98 reactors currently operating in the United States will expire before Peach Bottom Units 2 and 3 enter the SLR period. Tables 1 shows that seven reactors have permanently shut down since January 1, 2013, including some that had renewed operating licenses. And the operating license of Watts Bar Unit 2 will be the only license to expire after the requested 2053 expiration date for Peach Bottom Unit 2. Additionally, the pending closures of several other reactors in the next few years due to economic reasons have been announced (Beyond Nuclear 2018). And of the ten reactors under construction listed in Table 1 (i.e., those with TBD as the reactor license expiration date), only two reactors are actively under construction.

In addition, while it is possible that other owners will apply for and receive subsequent reactor operating license renewals, it is uncertain how many will operate into the period of extended operation being sought for Peach Bottom Units 2 and 3.

The declining trend in the number of operating reactors, which peaked at 109 in 1990 and has since gradually declined to the 98 reactors, can be seen in Table 2. This decline has reduced the amount of operating experience available for both pressurized water reactors (PWRs) and boiling water reactors (BWRs) like Peach Bottom.

The amount of operating experience available to assess the efficacy of aging management programs could be very credibly reduced significantly as currently operating reactors permanently shut down and few new reactors emerge to replace them.

Section 6.0 below describes how the subsequent license renewal application for Peach Bottom Units 2 and 3 relies on operating experience in aging management programs, but does not describe how sufficiency of operating experience necessary to sustain the effectiveness of these programs will be determined.

Table 1

Reactor	Reactor Supplier and Type	Shutdown or Operating License Expliration Date
Crystal River 3 (Note 1)	B&W LLP	02/20/13
Kewaunee (Note 2)	West 2LP	05/07/13
San Onofre Unit 2	CE	06/12/13
San Onofre Unit 3	CE	06/12/13
Indian Point Nuclear Generating, Unit 2 (Note 3)	WEST 4LP	09/28/13
Vermont Yankee (Note 4)	GE 4	12/29/14
Indian Point Nuclear Generating, Unit 3 (Note 3)	WEST 4LP	12/12/15
Fort Calhoun (Note 5)	CE	10/24/16
Oyster Creek Nuclear Generating Station (Note 6)	GE 2	09/17/18
Diablo Canyon Nuclear Power Plant, Unit 1	WEST 4LP	11/02/24
Waterford Steam Electric Station, Unit 3	COMB CE	12/18/24
Diablo Canyon Nuclear Power Plant, Unit 2	WEST 4LP	08/26/25
River Bend Station, Unit 1	GE 6	08/29/25
Perry Nuclear Power Plant, Unit 1	GE 6	03/18/26
Clinton Power Station, Unit 1	GE 6	09/29/26
Nine Mile Point Nuclear Station, Unit 1	GE 2	08/22/29
R.E. Ginna Nuclear Power Plant	WEST 2LP	09/18/29
Dresden Nuclear Power Station, Unit 2	GE 3	12/22/29
Comanche Peak Nuclear Power Plant, Unit 1	WEST 4LP	02/08/30
Seabrook Station, Unit 1	WEST 4LP	03/15/30
H. B. Robinson Steam Electric Plant, Unit 2	WEST 3LP	07/31/30
Monticello Nuclear Generating Plant, Unit 1	GE 3	09/08/30
Point Beach Nuclear Plant, Unit 1	WEST 2LP	10/05/30
Dresden Nuclear Power Station, Unit 3	GE 3	01/12/31
Palisades Nuclear Plant	CE	03/24/31
Surry Power Station, Unit 1	WEST 3LP	05/25/32
Pilgrim Nuclear Power Station	GE 3	06/08/32
Turkey Point Nuclear Generating Unit No. 3	WEST 3LP	07/19/32
Quad Cities Nuclear Power Station, Unit 1	GE 3	12/14/32
Quad Cities Nuclear Power Station, Unit 2	GE 3	12/14/32
Surry Power Station, Unit 2	WEST 3LP	01/29/33
Comanche Peak Nuclear Power Plant, Unit 2	WEST 4LP	02/02/33
Oconee Nuclear Station, Unit 1	B&W LLP	02/06/33
Point Beach Nuclear Plant, Unit 2	WEST 2LP	03/08/33
Turkey Point Nuclear Generating Unit No. 4	WEST 3LP	04/10/33
Peach Bottom Atomic Power Station, Unit 2	GE 4	08/08/33
Prairie Island Nuclear Generating Plant, Unit 1	WEST 2LP	08/09/33
Oconee Nuclear Station, Unit 2	B&W LLP	10/06/33
Browns Ferry Nuclear Plant, Unit 1	GE 4	12/20/33
Cooper Nuclear Station	GE 4	01/18/34
Duane Arnold Energy Center	GE 4	02/21/34

Table 1 (continued)

Reactor	Reactor Supplier and Type	Shutdown or Operating License Expliration Date
Three Mile Island Nuclear Station, Unit 1	B&W LLP	04/19/34
Arkansas Nuclear One, Unit 1	B&W LLP	05/20/34
Browns Ferry Nuclear Plant, Unit 2	GE 4	06/28/34
Peach Bottom Atomic Power Station, Unit 3	GE 4	07/02/34
Oconee Nuclear Station, Unit 3	B&W LLP	07/19/34
Calvert Cliffs Nuclear Power Plant, Unit 1	CE	07/31/34
Edwin I. Hatch Nuclear Plant, Unit 1	GE 4	08/06/34
James A. FitzPatrick Nuclear Power Plant	GE 4	10/17/34
Donald C. Cook Nuclear Plant, Unit 1	WEST 4LP	10/25/34
Prairie Island Nuclear Generating Plant, Unit 2	WEST 2LP	10/29/34
Brunswick Steam Electric Plant, Unit 2	GE 4	12/27/34
Millstone Power Station, Unit 2	CE	07/31/35
Watts Bar Nuclear Plant, Unit 1	WEST 4LP	11/09/35
Beaver Valley Power Station, Unit 1	WEST 3LP	01/29/36
St. Lucie Plant, Unit 1	CE	03/01/36
Browns Ferry Nuclear Plant, Unit 3	GE 4	07/02/36
Calvert Cliffs Nuclear Power Plant, Unit 2	CE	08/13/36
Salem Nuclear Generating Station, Unit 1	WEST 4LP	08/13/36
Brunswick Steam Electric Plant, Unit 1	GE 4	09/08/36
Davis-Besse Nuclear Power Station, Unit 1	B&W RLP	04/22/37
Joseph M. Farley Nuclear Plant, Unit 1	WEST 3LP	06/25/37
Donald C. Cook Nuclear Plant, Unit 2	WEST 4LP	12/23/37
North Anna Power Station, Unit 1	WEST 3LP	04/01/38
Edwin I. Hatch Nuclear Plant, Unit 2	GE 4	06/13/38
Arkansas Nuclear One, Unit 2	CE	07/17/38
Salem Nuclear Generating Station, Unit 2	WEST 4LP	04/18/40
North Anna Power Station, Unit 2	WEST 3LP	08/21/40
Sequoyah Nuclear Plant, Unit 1	WEST 4LP	09/17/40
Joseph M. Farley Nuclear Plant, Unit 2	WEST 3LP	03/31/41
McGuire Nuclear Station, Unit 1	WEST 4LP	06/12/41
Sequoyah Nuclear Plant, Unit 2	WEST 4LP	09/15/41
LaSalle County Station, Unit 1	GE 5	04/17/42
Susquehanna Steam Electric Station, Unit 1	GE 4	07/17/42
Virgil C. Summer Nuclear Station, Unit 1	WEST 3LP	08/06/42
McGuire Nuclear Station, Unit 2	WEST 4LP	03/03/43
St. Lucie Plant, Unit 2	CE	04/06/43
Catawba Nuclear Station, Unit 1	WEST 4LP	12/05/43
Catawba Nuclear Station, Unit 2	WEST 4LP	12/05/43
LaSalle County Station, Unit 2	GE 5	12/16/43
Columbia Generating Station	GE 5	12/20/43
Susquehanna Steam Electric Station, Unit 2	GE 4	03/23/44
Callaway Plant	WEST 4LP	10/18/44
Limerick Generating Station, Unit 1	GE 4	10/26/44

Table 1 (continued)

Reactor	Reactor Supplier and Type	Shutdown or Operating License Expliration Date
Byron Station, Unit 1	WEST 4LP	10/31/44
Grand Gulf Nuclear Station, Unit 1	GE 6	11/01/44
Wolf Creek Generating Station, Unit 1	WEST 4LP	03/11/45
Fermi Unit 2	GE 4	03/20/45
Palo Verde Nuclear Generating Station, Unit 1	CE80-2L	06/01/45
Millstone Power Station, Unit 3	WEST 4LP	11/25/45
Hope Creek Generating Station, Unit 1	GE 4	04/11/46
Palo Verde Nuclear Generating Station, Unit 2	CE80-2L	04/24/46
Braidwood Station, Unit 1	WEST 4LP	10/17/46
Shearon Harris Nuclear Power Plant, Unit 1	WEST 3LP	10/24/46
Nine Mile Point Nuclear Station, Unit 2	GE 5	10/31/46
Byron Station, Unit 2	WEST 4LP	11/06/46
Vogtle Electric Generating Plant, Unit 1	WEST 4LP	01/16/47
Beaver Valley Power Station, Unit 2	WEST 3LP	05/27/47
South Texas Project, Unit 1	WEST 4LP	08/20/47
Palo Verde Nuclear Generating Station, Unit 3	CE80-2L	11/25/47
Braidwood Station, Unit 2	WEST 4LP	12/18/47
South Texas Project, Unit 2	WEST 4LP	12/15/48
Vogtle Electric Generating Plant, Unit 2	WEST 4LP	02/09/49
Limerick Generating Station, Unit 2	GE 4	06/22/49
Watts Bar Nuclear Plant, Unit 2	WEST 4LP	10/22/55
Bellefonte Nuclear Power Station, Unit 1	B&W 205	TBD
Bellefonte Nuclear Power Station, Unit 2	B&W 205	TBD
Fermi Unit 3	GEH	TBD
North Anna Unit 3	ESBWR	TBD
Turkey Point Nuclear Generating Unit No. 6	AP1000	TBD
Turkey Point Nuclear Generating Unit No. 7	AP1000	TBD
Vogtle Electric Generating Plant, Unit 3	AP1000	TBD
Vogtle Electric Generating Plant, Unit 4	AP1000	TBD
William States Lee III Nuclear Station Unit 3	AP1000	TBD
William States Lee III Nuclear Station Unit 4	AP1000	TBD

NOTES:

(1) Crystal River 3's license renewal application was submitted 12/18/08 and withdrawn 02/06/13

(2) Kewaunee's reactor operating license was renewed 02/24/11

(3) The owner of Indian Point Units 2 and 3 applied for renewal of the reactor operating licenses. The renewal was contested. During the ensuing licensing proceedings, the original licenses expired. The reactors continued operating under the original licenses during the proceedings. An agreement was signed on January 8, 2017, for Unit 2 to permanently shut dfown by April 30, 2020, and Unit 3 to permanentlv shut down bv April 30. 2021. (New York State 2017)

(4) Vermont Yankee's reactor operating license was renewed 03/21/11

(5) Fort Calhouns' reactor operating license was renewed 11/04/03

(6) Oyster Creek's reactor operating license was renewed 04/08/09

Source: NRC 2018a, Appendices A, B, and C

Table 2

Reactor Years by Fiscal Year									
FY	Critical			Shutdown			Total		
Year	BWR	PWR	Total	BWR	PWR	Total	BWR	PWR	Total
1988	23.10	52.57	75.66	10.65	18.68	29.34	33.75	71.25	105.00
1989	22.71	51.76	74.47	11.54	21.74	33.28	34.25	73.50	107.75
1990	26.64	54.22	80.85	8.11	20.45	28.56	34.75	74.67	109.42
1991	25.53	57.41	82.94	8.89	17.59	26.48	34.42	75.00	109.42
1992	25.37	57.07	82.45	9.63	16.68	26.30	35.00	73.75	108.75
1993	26.66	57.53	84.20	8.34	14.88	23.22	35.00	72.42	107.42
1994	26.87	57.26	84.14	8.13	14.74	22.86	35.00	72.00	107.00
1995	28.44	60.06	88.50	6.56	11.94	18.50	35.00	72.00	107.00
1996	29.26	59.74	89.00	6.66	13.17	19.83	35.92	72.92	108.83
1997	27.18	53.50	80.68	8.82	19.33	28.15	36.00	72.83	108.83
1998	26.89	54.99	81.89	8.11	16.01	24.11	35.00	71.00	106.00
1999	29.55	60.29	89.84	5.45	10.71	16.16	35.00	71.00	106.00
2000	31.40	61.78	93.17	2.69	7.72	10.41	34.08	69.50	103.58
2001	31.77	61.73	93.50	2.23	7.27	9.50	34.00	69.00	103.00
2002	31.97	62.76	94.73	2.03	6.24	8.27	34.00	69.00	103.00
2003	31.28	61.73	93.01	2.72	7.27	9.99	34.00	69.00	103.00
2004	32.15	62.73	94.87	1.85	6.27	8.13	34.00	69.00	103.00
2005	31.09	62.22	93.31	2.91	6.78	9.69	34.00	69.00	103.00
2006	32.27	62.95	95.23	1.73	6.05	7.77	34.00	69.00	103.00
2007	31.97	63.15	95.11	2.45	5.85	8.30	34.42	69.00	103.42
2008	32.94	62.62	95.57	2.06	6.38	8.43	35.00	69.00	104.00
2009	32.21	63.39	95.60	2.79	5.61	8.40	35.00	69.00	104.00
2010	33.11	61.20	94.31	1.89	7.80	9.69	35.00	69.00	104.00
2011	31.77	61.04	92.81	3.23	7.96	11.19	35.00	69.00	104.00
2012	32.49	59.13	91.62	2.51	9.87	12.38	35.00	69.00	104.00
2013	31.60	58.33	89.93	3.40	9.25	12.65	35.00	67.58	102.58
2014	33.10	59.06	92.16	1.90	5.94	7.84	35.00	65.00	100.00
2015	32.01	60.61	92.62	2.24	4.39	6.63	34.25	65.00	99.25
2016	32.24	59.48	91.72	1.76	5.52	7.28	34.00	65.00	99.00
2017	31.49	59.47	90.96	2.51	5.53	8.04	34.00	65.00	99.00
Totals	**895.07**	**1779.78**	**2674.85**	**143.76**	**317.64**	**461.40**	**1038.83**	**2097.42**	**3136.25**

Source: NRC 2018b

6.0 Operating Experience in Aging Management During License Renewal at Peach Bottom

Exelon applied to the NRC on July 2, 2001, for the initial 20-year renewal of the operating licenses for Peach Bottom Units 2 and 3. The NRC issued the renewed licenses on May 7, 2003. Peach Bottom Unit 2 entered the period of extended operating on August 8, 2013, while Peach Bottom Unit 3 entered the period of extended operation on July 2, 2014. (NRC 2018c)

Appendix Q was added to the Updated Final Safety Analysis Report (UFSAR) for Peach Bottom Units 2 and 3 to describe the aging management programs developed for initial license renewal and relied upon by the NRC in renewing the reactor operating licenses (PBAPS 2017). The phrase "operating experience" does not appear in UFSAR Appendix Q. However, operating experience plays an implicit role in aging management during the period of extended operation due to the owner's reliance on industry inspection protocols. For instance, with respect to the reactor vessel and its internals, the NRC stated:

> *The BWR* [boiling water reactor] *Vessel and Internals Project (BWRVIP) guidelines are implemented through the Reactor Pressure Vessel and Internals ISI program. The Reactor Pressure Vessel and Internals ISI program is that part of the PBAPS ISI program that provides for condition monitoring of the Reactor Vessel and Internals using guidance provided by the BWRVIP and the BWR Owners Group alternate BWR Feedwater nozzle inspection requirements. … Program enhancements are implemented as the BWRVIP guidelines are revised.* (PBAPS 2017b, page Q.13)

Figure 2 shows how the aging management of many structures and components of at Peach Bottom is conducted using BWRVIP guidelines. And the aging management programs at Peach Bottom are enhanced when BWRVIP guidelines are revised.

Revisions to BWRVIP guidelines are managed for the industry by the Electric Power Research Institute:

> *The BWRVIP will evaluate the need to revise BWRVIP guidelines based on industry operating experience. EPRI will act as the program manager responsible for maintaining technical documents as directed by the BWRVIP.* (EPRI 2011, page 1-5)

Indirectly therefore, the aging management programs for Peach Bottom Units 2 and 3 rely on EPRI evaluating operating experience and they revise, when necessary, the BWRVIP guidelines used to manage aging effects at the plant.

Figure 2

PBAPS UFSAR

Reactor Pressure Vessel And Internals BWRVIP Document Applicability

Reactor Pressure Vessel Components	Reference
Reactor pressure vessel components	BWRVIP-74
Vessel shells	BWRVIP-05
Shroud support attachments	BWRVIP-38
Nozzle safe ends	BWRVIP-74
Core support plate	BWRVIP-25
Core ΔP / SLC nozzle	BWRVIP-27
Core spray attachments	BWRVIP-48
Jet pump riser brace attachments	BWRVIP-48
Other attachments	BWRVIP-48
CRDH stub tubes	BWRVIP-47
ICM Housing penetrations	BWRVIP-47
Instrument penetrations	BWRVIP-49
Reactor Internals Components	
Shroud support	BWRVIP-38
Shroud	BWRVIP-76
Core support plate	BWRVIP-25
Core ΔP / SLC line	BWRVIP-27
Access hole covers	(Note 1)
Top guide (Note 2)	BWRVIP-26
Core spray lines	BWRVIP-18
Core spray spargers	BWRVIP-18
Jet pump assembly	BWRVIP-41
CRDH stub tubes	BWRVIP-47
CRDH guide tubes	BWRVIP-47
In-core housing guide tubes, LPRM & WRNMS dry tubes	BWRVIP-47
Note 1. GE SIL 462 for Unit 2 only.	
Note 2: The Reactor Pressure Vessel and Internals ISI program were enhanced to require inspection of top guide similar to the inspection of CRDH guide tubes.	

Source: PBAPS, page Q.14

In July 2018, Exelon applied to the NRC for a second renewal of the operating licenses for Peach Bottom Units 2 and 3 (Exelon 2018). As for the initial license renewal, Exelon relied heavily on the BWRVIP guidelines for the aging management programs described in the subsequent license renewal application. For example, Exelon's application for subsequent license renewal states:

> *As discussed above, specifying supplemental inspections beyond the inspections recommended by the current BWRVIP guidelines are not necessary. The BWRVIP is chartered to review and trend operating experience from the BWR fleet relative to implementation of recommended inspections and revise the recommendations as appropriate in accordance with BWRVIP-94-R2-NP and NEI*

> *03-08. As new or revised inspection recommendations are recommended by the BWRVIP, they are required to be implemented in accordance with BWRVIP-94-R2-NP and NEI 03-08.* (Exelon 2018, page 3.1-26)

The use of operating experience for aging management programs at Peach Bottom is extensively described in Appendix B to the subsequent license renewal application (Exelon 2018, pages B-6 and B-7) (emphasis added):

> *Operating experience from internal (also referred to as plant-specific) and external (also referred to as industry) sources is captured and systematically reviewed on an ongoing basis in accordance with the Quality Assurance program, which meets the requirements of 10 CFR Appendix B, and the Operating Experience (OPEX) program. … The OPEX program interfaces with and relies on active participation in the "Institute of Nuclear Power Operations" Operating Experience program, as endorsed by the NRC.*
>
> *Operating experience is used at PBAPS to enhance plant programs, prevent repeat events, and prevent events that have occurred at other plants. As part of the Exelon fleet, PBAPS personnel receive operating experience (internal and external to Exelon Nuclear) daily. The OPEX process includes screening, evaluation, and acting on operating experience documents and information to prevent or mitigate the consequences of similar events. The OPEX process includes review of operating experience from external and internal sources.* ***External operating experience includes INPO documents, NRC documents (e.g., GALL Revisions, Information Notices, Regulatory Information Summaries, Interim Staff Guidance), and other documents (e.g., Licensee Event Reports, 10 CFR Part 21 Reports), as well as relevant research and development information. Internal operating experience includes event investigations, trending reports, and lessons learned from in-house events as captured in program health reports, program assessments, and in the 10 CFR Part 50, Appendix B corrective action program.***
>
> *The Exelon fleet OPEX program that is implemented at PBAPS is an ongoing program that conforms to the recommendations of LR-ISG-2011-05, "Ongoing Review of Operating Experience," and is consistent with the expectations outlined in NUREG-2192 (SRP-SLR), Appendix A.4, "Operating Experience for Aging Management Programs."* ***The systematic review of plant-specific and industry operating experience concerning aging management and age-related degradation ensures that the license renewal aging management programs (AMPs) are, and will continue to be, effective in managing the aging effects for which they are credited. Operating experience involving age-related degradation is tracked and trended such that adverse trends are entered into the corrective action program for evaluation.*** *Potential aging issues associated with SSCs within the scope of license renewal are evaluated with regard to: (a) materials of construction, (b) operating environment, (c) aging effects, (d) aging mechanisms, and (e) aging management programs, to determine if changes to AMPs, or new AMPs are needed. The AMPs are either enhanced or new AMPs developed, as appropriate, when it is determined through the evaluation of operating experience that the effects of aging may not be adequately managed. AMPs are informed by the review of operating experience on an ongoing basis, regardless of the AMP's implementation schedule. … In addition, the Exelon process requires the periodic conduct of AMP effectiveness reviews, such that they are performed at least once within every five-year period, and refers to and is consistent with the guidance of NEI 14-12, "Aging Management Program Effectiveness."*
>
> *Each AMP summary in this appendix contains a discussion of operating experience relevant to the program. This information was obtained through the review of internal operating experience captured by the corrective action program, program assessments, program health reports, and*

through the review of external operating experience. Additionally, operating experience was obtained through interviews with system engineers, program engineers, and other plant personnel. New programs utilized internal and/or external operating experience as applicable, and the AMP summaries in this appendix discuss the operating experience and associated corrective actions as they relate to implementation of the new program. ***The operating experience in each AMP summary identifies past corrective actions, some of which have resulted in program enhancements and provides objective evidence that the effects of aging have been, and will continue to be, adequately managed so that the intended functions of the structures and components within the scope of each program will be maintained during the second period of extended operation.***

The subsequent license renewal application also describes instances where external operating experience has resulted in changes to aging management programs. For example, the computer program CHECWORKS is used to predict piping wear rates and corresponding remain service life as part of the aging management program for flow-accelerated corrosion. The computer model relies on factors including industry operating experience to identify susceptible piping location to measure wall thinning since not every foot of every pipe is monitored (Exelon 2018, page B-56). A licensee event report submitted to the NRC in 2015 by the owner of the Davis-Besse nuclear plant described how a restricting orifice installed in a pipe was shown in CHECWORKS as having an opening size of 3.0 inches but found to actually have an opening of 0.859 inches. Using the improper orifice size, CHECWORKS calculated a non-conservative wear rate for the piping downstream of the orifice. The pipe wore out and failed. Workers discovered that 30 of the 70 orifices modeled by CHECWORKS had the wrong size dimensions. Workers at Peach Bottom determined this operating experience to be potentially applicable to the plant. Ensuing examination "…identified several discrepancies in the model involving pipe and flow element configuration" (Exelon 2018, page B-60).

Another example of an instance where internal operating experience has resulted in changes to aging management programs relates to the refueling water storage tank (RWST). The RWST was not included within the scope of aging management programs for the initial license renewal. But a modification to the plant to support extended power uprate changed the licensing basis in 2014 to credit using the RWST in responding to Appendix R (i.e., fire) and anticipated transient without scram (ATWS) events. The RWST was added to the license renewal scope. Silica levels in the RWST exceeded the chemistry goals during transfers of irradiated fuel bundles from the spent fuel pool to the Independent Spent Fuel Storage Installation (ISFSI) because spent fuel pool water was drained to the RWST to control water level in the pool as canisters were lowered into it. Corrective actions included treating the RWST water after transfers were completed for the purpose of lowering silica levels to within specifications (Exelon 2018, page B-23).

Another example involves the June 2010 discovery of tritium in rain water samples within the berm around the Unit 1 condensate storage tank (CST) at LaSalle. The source of the tritium was determined to be leakage through the CST caused by corrosion. The internal operating experience report from this event prompted workers to change how they inspected the CSTs and RWSTs at Peach Bottom. While no through-wall leaks were identified, several locations were found where corrosion had reduced tank wall thickness below the minimum allowable value (Exelon 2018, pages B-111 and B-112).

The aging management programs used during the initial period of extended operation of Peach Bottom Units 2 and 3 and those proposed for use during the subsequent license renewal rely on operating experience feedback. The subsequent license renewal application described in considerable detail how internal and external operating experience has demonstrated the effectiveness of aging management programs. Time and again, the subsequent license renewal application made statements like:

> *The following examples of operating experience provide objective evidence that the BWR Stress Corrosion Cracking program will be effective in assuring that intended functions are maintained consistent with the current licensing basis for the second period of extended operation:* (Exelon 2018, page B-36)

See also Exelon 2018, pages B-16 (in-service inspection program), B-22 (water chemistry management program), B-28 (reactor head closure stud bolting program), B-32 (vessel attachment welds program), B-40 (BWR penetrations program) , B-49 (BWR vessel internals program), B-54 (thermal aging embrittlement of cast austenitic stainless steel program), B-57 (flow-accelerated corrosion program), B-60 (industry operating experience program), B-66 (bolting integrity program), and B-72 (open-cycle cooling water system program). Exelon's extensive discussions of how operating experience resulted in aging effects being found and fixed provide irrefutable testimony to the value of operating experience feedback.

The subsequent license renewal application describes how operating experience has been used and how it will continue to be used. But the subsequent license renewal application is silent regarding the amount of operating experience that is necessary, or the sources for external operating experience needed to maintain the effectiveness of the aging management programs. While Exelon acknowledges, for example, that external operating experience identified problems and led to corrective measures for how components were modeled within the CHECWORKS program used to manage the effects of flow-accelerated corrosion, it does not explain how Exelon can continue to obtain and evaluate external operating experience if it becomes less and less available. The subsequent license renewal application is silent about the credible closures of reactors and the reduction in the amount of external operating experience available.

The license renewal rule requires applicants to submit applications that explain how the effects of aging will be effectively managed throughout the period of extended operation. The NRC's Standard Review Plan for Subsequent License Renewal (NRC 2017b) requires applications to describe how operating experience will be used on an ongoing basis to assure the effectiveness of aging management programs.

The subsequent license renewal application for Peach Bottom Units 2 and 3 fails to explain how the amount of operating experience available will be determined to be sufficient such that the effectiveness of the aging management programs can be maintained.

Put another way, the subsequent license renewal application provides numerous examples of how external operating experience resulted in effective aging management programs at Peach Bottom. But the subsequent license renewal application fails to describe how aging management programs would continue to remain effective should the amount of external operating experience be significantly reduced as reactors permanently shut down. If availability of sufficient external operating experience yielded effective aging management programs, then unavailability of sufficient operating experience would at undermine the continued effectiveness of those programs as discussed below in Section 7.0.

7.0 Operating Experience May Become Insufficient to Maintain Effective Aging Management

When crafting its license renewal rule, the NRC expressly identified the need for sufficient operating experience information to properly establish the scope and content of aging management programs (NRC 1991, 56 FR at page 64943). But neither the NRC nor the industry have identified, qualitatively or quantitatively, how operating experience information sufficiency is maintained throughout the period of extended operation.

For instance, as described on pages 9-12 above, the nuclear industry, Exelon, and NRC use monitoring and evaluation processes to identify sources of operating experience (e.g, licensee event reports, inspection findings, etc.) and how the information will be handled (e.g., evaluated by qualified individuals with corrective action reports initiated for out-of-normal findings.) The outcomes from these processes have prompted revisions to aging management programs, including assessments of how effectively each step in the process is being implemented. But none of the processes seek to ascertain whether the amount of operating experience is sufficient to enable the revisions needed to maintain effective aging management programs. In other words, they fail to specify the “critical mass” of operating experience information needed to confirm the continued adequacy of aging management programs or trigger the necessary upgrades.

An example of this deficit can be seen in the Electric Power Research Institute (EPRI) manages the Boiling Water Reactor Vessel and Internals Project Program Implementation Guide, BWRVIP-94NP (EPRI 2011). This guide controls how other BWRVIP guidelines are updated when necessary. Appendix C to BWRVIP-94NP describes the “*actions to be taken when an emergent materials issue with generic significance to the industry is identified at a nuclear power plant*” (ERPI 2011, page C-1). Emergent issues that can trigger these actions include:

1. *Any through wall leakage is identified in a BWR vessel (includes the nozzle assemblies out to the process piping to safe-end or safe-end-extension weld)*

2. *An unplanned plant shutdown is elected due to BWR vessel or internals materials issue*

3. *Inspection results are unexpected and have the potential for generic implications*

4. *Mitigation results are unexpected and have the potential for generic implications*

5. *Operating experience that is beyond that previously reported in INPO's OE database.* (EPRI 2011, page C-1)

This BWRVIP guide does not address how the potential reduction in the number of operating reactors could adversely affect the identification of emerging issues warranting consideration of revisions to BWRVIP guides. All things being equal, X issues emerging from a fleet of 98 operating reactors would yield half that number if closures reduce the size of the fleet to 49 reactors. This BWRVIP guide does not describe how to determine whether the amount of operating experience remains sufficient to sustain aging management program effectiveness.

Similarly, Nuclear Energy Institute (NEI) guide NEI 14-12, “Aging Management Program Effectiveness,” (NEI 2014) has the stated purpose of providing “*a standard approach for the self-assessment process for periodically evaluating the effectiveness of aging management programs*” (NEI 2014, page i). One of the five Attributes of Effectiveness stated in this guide is “*Industry and site-specific operating experience is routinely evaluated and program adjustments made as necessary*” (NEI 2014, page 2). Section 4 of this guide specifies Performance Criteria to be applied during the periodic self-assessments. Criterion 4.10 addresses operating experience and has two elements:

a. *Industry operating experience is evaluated and program adjustments are made as necessary.*

b. *Plant-specific operating experience is used to adjust programs as necessary* (NEI 2014, page 7)

This NEI guide does not address how the potential reduction in the number of operating reactors could adversely affect the amount of operating experience available to make necessary adjustments to aging management programs.

> NOTE: In a presentation to the NRC, NEI indicated that guide NEI 14-13, "Use of Industry Operating Experience for Age-Related Degradation and Aging Management Programs," described the "*Industry approach for collecting and sharing OE* [operating experience] *for passive long-lived components – based on plant Corrective Action Program*" (NEI 2015b, slide 3). This guide could not be found in NRC's ADAMS public library. The NRC's Public Document Room (PDR) staff was contacted for help finding this record. On October 18, 2018, the PDR staff responded with information about available records that reference this guide, but not the guide itself. ADAMS was re-checked on November 12, 2018, and internet searches of the NEI website and web failed to produce the guide. Whether this non-public guide describes how operating experience and its use in aging management program effectiveness may be impacted by permanent closure of reactors cannot be determined.

A third example can be found in NEI 03-08, "Guidelines for the Management of Materials Issues" (NEI 2010). Prompted by the degradation of the reactor vessel head at Davis-Besse and other materials aging issues, NEI developed NEI 03-08 which has subsequently been revised twice. By its own terms, NEI 03-08 "*provides the framework within which all materials degradation and aging management work will be performed*" (NEI 2010, page 1). And NEI 03-08 also describes the need to review operating experience for potential impact on aging management programs (NEI 2010, page 4). It does not, however, address the question of what amount of operating experience is necessary to provide adequate feedback.

To illustrate the potential problem, suppose that Nine Mile Point Unit 1 had permanently shut down prior to 2003. The top guide cracking identified between 2003 and 2005 that led to the NRC requiring appropriate aging management programs in future license renewal applications (see discussion on page 14 above and NRC 2005, page 228) would not have been identified. There would have been no report of cracking for the industry, Exelon, and NRC operating experience processes to evaluate and make necessary revisions to the aging management programs.

To further illustrate this potential problem, suppose that the three reactors at Oconee had permanently shut down prior to 2001. Workers would not have discovered and reported the cracked control rod drive mechanism nozzle and the NRC would not have issued Bulletin 2001-01 (NRC 2001a) requiring owners of other vulnerable reactors to conduct inspections at a pace dictated by susceptibility to the problem. The cracked nozzle at Davis-Besse and the degradation of the reactor vessel head might not have been detected before the widening hole breached the reactor coolant pressure boundary.

Permanent closures of nuclear power reactors will reduce the amount of operating experience to a point that aging management programs may be significantly impaired. NRC guidance documents do not describe how to determine whether sufficient operating experience information is available.

NRC guidance documents also do not ensure that a lack of sufficient operating experience will be noticed or flagged in the normal course of internal process reviews. As discussed in Section 2, for example, the

NRC requires owners to review operating experience and revise aging management programs when necessary. The NRC further requires that owners place information in the Updated Final Safety Analysis Report (UFSAR) to enable program changes to be made via 10 CFR 50.59. Exelon can review operating experience information (e.g., license event reports, vendor advisories, NRC generic communications, etc.) for potential impacts on aging management programs. But such reviews alone cannot sustain the effectiveness of aging management programs without reliable means of gauging whether the amount of operating experience information is sufficient.

Similarly, the subsequent license renewal application describes features like effectiveness assessments of the aging management programs performed at least once every five years (Exelon 2018, pages B-6 and B-7). But even the total elimination of operating experience reports would not necessarily be flagged as a potential impairment to the aging management programs without explicit descriptions of how each aging management program relies upon operating experience. With focus solely on process, the assessments would seek to determine whether operating experience reports were reviewed by qualified individuals, whether proper determinations were reached, and whether appropriate steps were taken for adverse determinations. If there were zero operating experience reports available, the process assessment could find no deficiencies. With explicit descriptions of how operating experience factors into individual aging management programs, the period assessments could also evaluate whether reductions or elimination of operating experience due to reactor closures has adversely affected the effectiveness of the programs.

Given the credible potential for the amount of operating experience to decline, Exelon's subsequent license renewal application and UFSAR must explicitly discuss the sources of operating experience for the various aging management program and the "critical mass" of that information needed to maintain their effectiveness. If the "critical mass" from operating reactors is not sufficient, alternate sources such as those identified below in Section 8 should be identified.

8.0 Alternate Sources of Operating Experience

Operating experience has traditionally come from the fleet of nearly 100 operating nuclear power reactors. As discussed in Section 5, the size of that fleet has decreased nearly ten percent over the past two decades. The reactor closures announced by owners coupled with the fact that the current operating licenses for all but one of the non-Peach Bottom reactors expires before either Peach Bottom reactor reaches the end of the period of subsequent extended operation strongly suggests that the volume of traditional operating experience could significantly decrease in the future.

The subsequent license renewal application for Peach Bottom describes how operating experience has demonstrated the effectiveness of aging management programs for specific components and structures. The application does not describe the extent to which these aging management programs relied on operating experience to sustain that effectiveness. Essentially, the application assumes that aging management programs will be upgraded using whatever operating experience is available.

But the body of operating experience available to Exelon during the subsequent license renewal term may be smaller than the body of experience available during the first license renewal term, and the reduction may be significant. As described in Section 5, the permanent shutdown of reactors could significantly reduce the amount of operating experience available. Thus, descriptions of how various aging management programs depend on internal and external operating experience are needed in the subsequent license renewal application to support determinations about whether the amount of external operating experience is sufficient or whether alternative sources should be used. If external operating experience plays a significant contribution to the effectiveness of aging management programs, then removal or reduction in the amount of external operating experience could impair the programs.

There is a credible potential for the amount of external operating experience to significantly decrease. The subsequent license renewal application for Peach Bottom must address this potential and explain how the flow of external operating experience will be assessed for sufficiency. The application must also address how effectiveness of aging management programs will be sustained should external operating experience be determined to be insufficient.

There are alternatives to operating experience that could be employed to maintain the effectiveness of aging management programs. The options include:

- Increasing the scope and/or frequency of inspections at Peach Bottom to replace diminished external operating experience with expanded internal operating experience.

- Evaluating the physical properties of materials removed from Peach Bottom and other reactors during routine maintenance and modification activities.

- Evaluating the physical properties of materials harvested from reactors that have permanently shut down.

Increasing the Scope and/or Frequency of Inspections at Peach Bottom

The first alternative is straight-forward. Structures and components are typically inspected on a sample basis. The sample sizes selected for inspections and/or the frequencies of the inspections could be increased to supplement diminished operating experience from external sources with expanded internal operating experience to sustain confidence in the aging management program effectiveness.

Evaluating Materials Removed During Routine Activities at Operating Reactors

A second alternative, evaluating materials removed during routine activities at Peach Bottom and other operating reactors, is also readily available. Materials are routinely removed from Peach Bottom during normal maintenance activities. For example, during the 21st refueling outage for Peach Bottom Unit 3, a 6-inch diameter section of the Code Class 1 piping for the reactor core isolation cooling (RCIC) system connection to the feedwater line was replaced (Herr 2018, Table 2); during the 20th refueling outage for Peach Bottom Unit 3, the 94 degree lug in the reactor vessel was repaired and the reactor water cleanup (RWCU) system piping upstream of check valve CHK-3-12-062 was replaced (Navin 2016, Table 2); during the 20th refueling outage for Peach Bottom Unit 2, Code Class 1 reactor vessel flange N6B was replaced, the Code Class M stud on suppression chamber hatch N-200B was replaced, and the Code Class 2 large bore weld on residual heat removal cross-tie 10-2DA20-19 was replaced (Navin 2015, Table 2); and during the 19th refueling outage for Peach Bottom Unit 2, the Code Class M stud on suppression chamber hatch B-200A was replaced and the Code Class 2 flange studs for torus penetration N-213A were replaced (Moore 2013, Table 2). If evaluated for aging effects, these components could yield valuable information.

In addition to the materials routinely removed from Peach Bottom, materials are routinely removed from other reactors. For example. three core plate plugs were replaced during the 2005 refueling outage for Browns Ferry Unit 1, all twelve source range monitor (SRM) and intermediate range monitor (IRM) dry tubes were replaced during the 2006 refueling outage for Browns Ferry Unit 1, the auxiliary wedge on jet pump 11 was replaced during the 2016 refueling outage for Dresden Unit 3, and all twelve SRM/IRM dry tubes during replaced during the 2000 refueling outage for Hope Creek (EPRI 2017, pages 9, 17, 62, and 91 respectively). Additionally, all 20 jet pump beams were replaced during the 2003 refueling outage for Dresden Unit 2, all twelve SRM/IRM dry tubes were replaced during Refueling Outage 11 at Fermi Unit 2, and core shroud bolts 2 and 33 were replaced during the 2015 refueling outage for Fermi Unit 2 (EPRI 2016, pages 12, 40, and 45 respectively). And baffle former bolts were removed from the Ginna nuclear plant in 2016 and obtained by the Department of Energy for evaluation through its Light Water Reactor Sustainability Program (DOE 2017b, page A-3).

The removal of electrical cables from several operating nuclear plants provides a good example of how these components can yield valuable insights about aging management. Several cables were removed from Fermi Unit 2 in 2014 for forensic examination (Rumuhali 2017, page 21). Cables were also removed from the Palo Verde nuclear plant site for examination (Rumuhali 2017, page 22). While the cables from Fermi had been installed in the plant and exposed to temperature, humidity, and radiation during reactor operation, the cables from Palo Verde had only experienced storage in the warehouse onsite for more than 20 years. The cables had never been installed in the plant. The examinations shed insights about insulation degradation over time versus degradation aided by exposure to harsher environmental conditions.

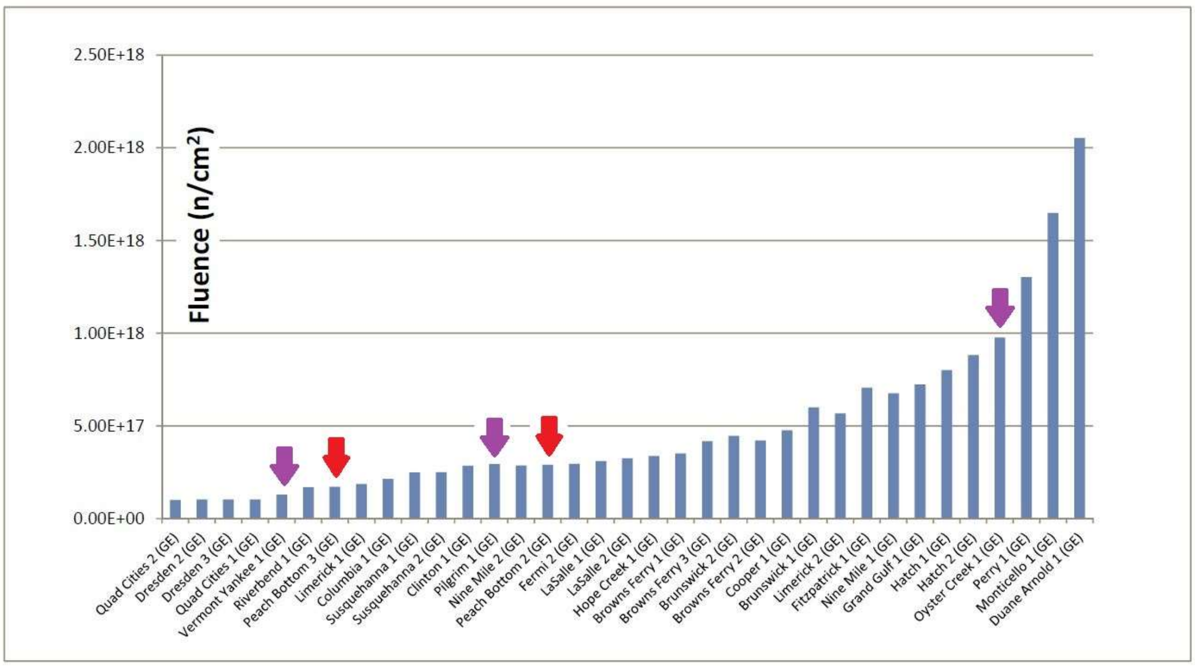
Some of the materials routinely removed from Peach Bottom and other reactors could be sent for analysis of their physical properties. Results from the analyses about degradation mechanisms and rates could substitute for and/or supplement traditional operating experience to sustain confidence in the effectiveness of aging management programs during the period of extended operation as reactors permanently shut down.

Evaluating Materials Harvested From Permanently Shut Down Reactors

A third alternative involves harvesting materials from reactors that have been permanently shut down. Continued operation of these reactors could have enabled traditional operating experience to properly support aging management programs. Harvesting materials after their closure enables them to still perform this role, albeit via a different means. In 2015, the NRC reported that materials had so far only been harvested from Zion in the United States and Zorita in Spain (Hiser and Hull 2015).

Figure 3 illustrates how materials harvested from permanently shut down reactors could benefit the effectiveness of aging management programs for Peach Bottom Units 2 and 3, either by confirming the programs are adequate or identifying where they need to be improved. The estimated neutron radiation levels (fluence) of the reactor pressure vessels at U.S. boiling water reactors after 80 years of operation is plotted in the figure. The red arrows point to the projected fluences of the Peach Bottom Unit 2 and 3 reactor pressure vessels. The purple arrows point to the projected fluences for the Vermont Yankee, Pilgrim, and Oyster Creek reactor pressure vessels. While none of these reactors operated for 80 years, samples of the reactor pressure vessels from these permanently shut down reactors (or soon to be shut down in Pilgrim's case) could increase the understanding of radiation effects on embrittlement of the reactor pressure vessels on Peach Bottom Units 2 and 3.

Figure 3



Summary of US BWR Fleet Fluence extrapolated to 80 years (E > 1.0 MeV)

Source: LPI 2013, Figure 3.2

Figure 3 illustrates the concept of using information from materials harvested from permanently shut down reactors to inform aging management programs for Peach Bottom. Materials harvested from permanently shut down reactors may provide the information needed to replace the operating experience lost as reactors shut down.

An example of the use of harvested components to understand aging effects is provided by the Zion nuclear plant. Samples were harvested from the Zion Unit 1 reactor pressure vessel following its permanent shut down and the samples are being evaluated under DOE's Light Water Reactor Sustainability Program. The reason for this harvesting and evaluation project was explained:

> *This project is critically important because access to materials from active or decommissioned NPPs* [nuclear power plants] *provide an invaluable resource for which there is limited operational data or experience to inform relicensing decisions and assessments of current*

degradation models to further develop the scientific basis for understanding and predicting long-term environmental degradation behavior. (Rosseel 2018, page xi)

Segments of electrical cables have been harvested from permanently shut down reactors:

- Electrical cables up to 30-feet long of various insulation materials were harvested in 2016 from Zion Unit 2 following its permanent shut down. (Rumuhali 2017, page 21)
- Electrical cables were harvested in 2015 from Crystal River 3 following its permanent shut down. (Rumuhali 2017, page 21)

Both the NRC and the DOE, through its national laboratories, have stated the virtues and needs for insights gain from harvesting materials from permanently shut down reactors in assuring that effective aging management programs can be maintained. The value of the harvested cables was described by the DOE:

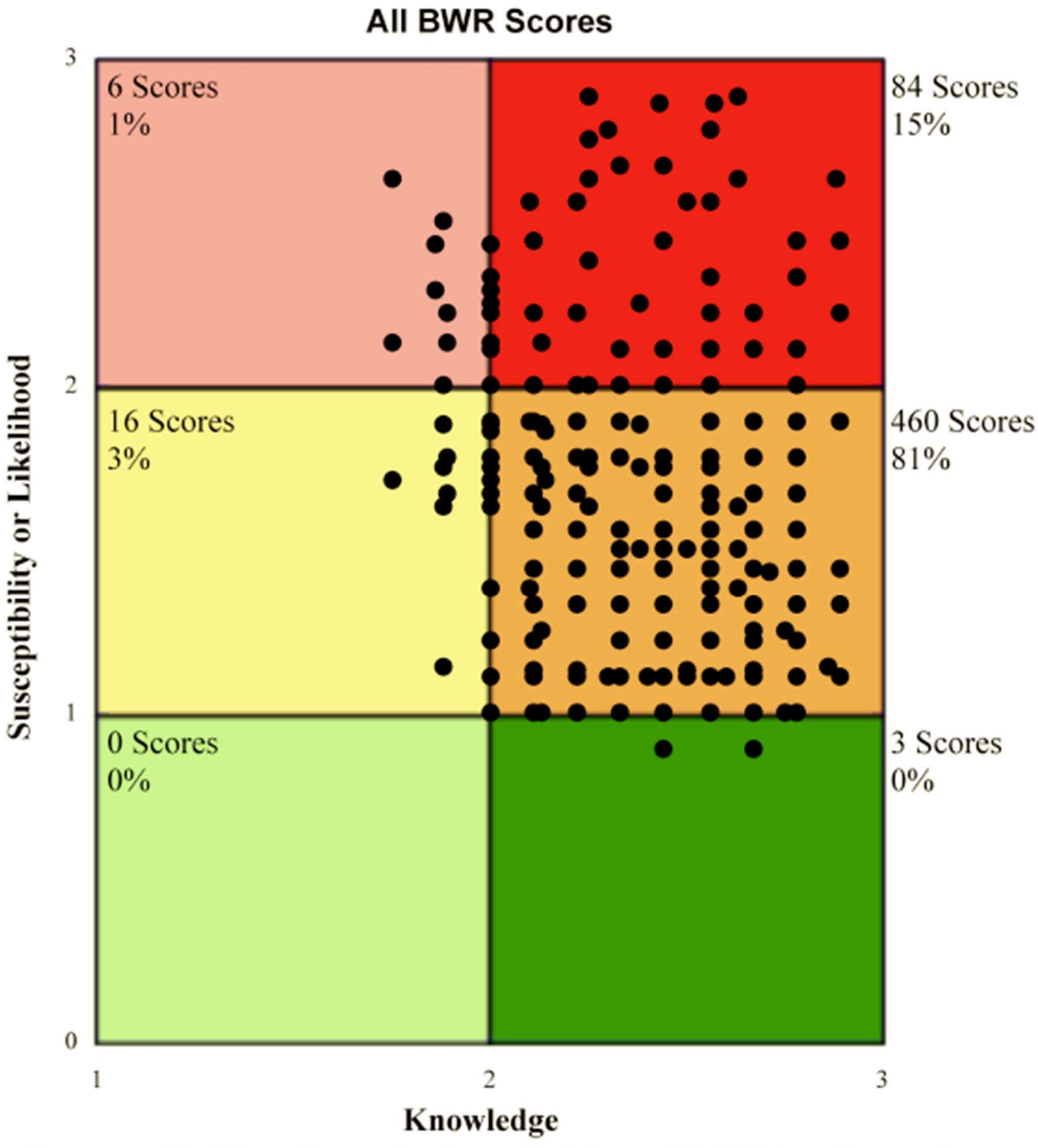
> *A key component of the effort to better understand cable material aging behavior is the availability of representative samples of cables that have been installed in operating light water reactors and have experienced long term service. Unique access to long term service cables, including relatively rich information on cable identity and history, occurred in 2016 through the assistance of the Electric Power Research Institute (EPRI). EPRI facilitated DOE receipt of harvested cables from the decommissioned Crystal River Unit 3 (CR3) pressurized water reactor representing six of the nine most common low voltage cable manufacturers (EPRI 103841R1): Rockbestos, Anaconda Wire and Cable Company (Anaconda), Boston Insulated Wire (BIW), Brand-Rex, Kerite and Okonite. Cable samples received had been installed in the operating plant for durations ranging from 10 years to 36 years.* ***These cables provide the opportunity to assess actual in-plant material aging and compare it to the expectations for service aging implied in original equipment qualification.*** *The received samples are from cables manufactured as early as 1971 and as late as 1998.* (DOE 2017a, page iv) (emphasis added)

It has been reported that degradation of cast austenitic stainless steel (CASS) would benefit form examination of samples harvested from permanently shut down reactors:

> *At present, accelerated aging of CASS in the laboratory and computer simulations of microstructural changes are the main tools used to understand the aging of CASS in service. It would be useful to harvest reactor materials to validate the current accelerated aging program, computer models, and existing regulatory positions. Microscopy and mechanical testing of harvested materials will improve our understanding of aging behavior. In addition, accelerated aging of harvested materials will provide information on new degradation mechanisms that could crop up under extended life.* ***While radiation damage has not been a concern in CASS, it would be prudent to harvest both unirradiated material (piping, pumps, etc.) and irradiated material (reactor internals) so that radiation effects on degradation under life extension can be reliably evaluated***. (Rumuhali 2017, page 11) (emphasis added)

Harvesting materials comes at a cost and also with a risk to workers collecting and handling radioactively contaminated samples. Research studies have identified high priority needs that could justify the cost and risk of harvesting. For example, the NRC formed an expert panel to conduct an expanded materials degradation assessment. The expert panel characterized various materials by two factors (1) their susceptibility to degradation, and (2) the state of knowledge about degradation mechanisms and rates. Figure 4 plotted the expert panel's results. Most materials fell into the top and middle boxes on the right-hand side where knowledge about degradation mechanisms was high. The priorities would be the materials in the top and middle boxes on the left where susceptibility to degradation is high but knowledge about degradation mechanisms is low.

Figure 4



Susceptibility–Knowledge plot for all BWR categories

Source: NRC 2014b, Figure 9.8

The materials deemed to have high susceptibility to degradation but less awareness about the nature of that degradation would be priority candidates for harvesting. Table 3 lists the materials that the expert panel binned into the upper left box of Figure 4.

Table 3			
Summary of all low Knowledge categories for BWRs			
Material/Environment	**Degradation Mode**	**Average Knowledge**	**Average Susceptibility**
X750 in reactor water – low fluence irradiation up to 0.5 dpa	FR	1.89	2.13
304 SS in reactor water – high fluence more than 8 dpa up to 20 dpa	SCC-HWC	1.86	2.43
304 SS in reactor water – high fluence more than 8 dpa up to 20 dpa	FR	1.86	2.29
304 SS HAZ in reactor water – high fluence more than 8 dpa up to 20 dpa	FR	1.86	2.29
316 SS in reactor water – moderate fluence up to 8 dpa	FR	1.88	2.00
316 SS HAZ in reactor water – high fluence more than 8 dpa up to 20 dpa	FR	1.75	2.13
Notes: DPA = Displacements per Atom, FR = Fracture Resistance, HAZ = Heat-Affected Zone, HWC = Hydrogen Water Chemistry, SCC = Stress Corrosion Cracking, SS = Stainless Steel			
Source: NRC 2014b, Table 9.5			

The subsequent license renewal application for Peach Bottom must describe the determinations made regarding the amount of traditional operating experience needed to assure that effective aging management programs will be maintained throughout the period of extended operation.

The subsequent license renewal application describes various aging management programs and how past operating experience played a role crafting the programs. But it fails to describe the sources and amounts of operating experience necessary to sustain the effectiveness of these programs.

A poster session at the NRC's Regulatory Information Conference in March 2018 addressed the timely opportunity for strategic collection of materials harvested from permanently shut down reactors to support subsequent license renewals (SLRs):

> *Extended plant operations and SLR raise a number of issues that may require further research to understand and quantify aging mechanisms. Meanwhile, in recent years, a number of NPPs* [nuclear power plants]*, both in the U.S. and internationally, have shut down for various reasons, including economy, political and technological challenges. Unlike in the past when there were very few plants shutting down these developments provide opportunities for harvesting components that were aged in representative light-water reactor environments.* (NRC 2018e)

The poster session explained that examination of materials obtained from nuclear reactors can provide insights that simply cannot be obtained from alternate methods, such as computer simulations and accelerated aging of materials in laboratory settings:

> *Simultaneous thermal and irradiation conditions are difficult to replicate, and accelerated aging may not be feasible for mechanism sensitivity to dose rate*. (NRC 2018e)

Without explicit discussion within the subsequent license renewal application for Peach Bottom of aging management program dependence on operating experience feedback, the opportunity for harvesting materials from permanently shut down reactors or collected from operating reactors may be lost. As noted by researchers at the Pacific Northwest National Laboratory:

> *Recent experiences (such as Zion and Crystal River Unit 3) showed the process of harvesting can be expensive. A related challenge was the complexity of securing engineering and labor support for a forensic harvesting task when the primary contractor in charge of the operation is primarily focused on dismantling the plant.* (Rumuhali 2017, page 24)

These researchers identified several requirements for harvesting plans. At the top of their list was this requirement:

> *Clearly identifying the need for harvesting the material. This will require defining the knowledge gaps that will be addressed and how these gaps are relevant to SLR.* (Rumuhali 2017, page 24)

The subsequent license renewal application for Peach Bottom must explicitly describe how operating experience is used to maintain the effectiveness of the various aging management programs. Only by doing so will knowledge gaps be properly defined. The knowledge gaps are known to exist today (as described in Section 4) or could emerge when permanent shut down of reactors restricts the available of operating experience information. Defining these knowledge gaps is an essential step in determining the actions necessary to manage the gaps. The actions might entail increasing the scope and/or frequency of testing and inspections at Peach Bottom, or evaluating materials removed during routine activities at operating reactors, or evaluating materials harvested from permanently shut down reactors.

Correcting the deficiency in the subsequent license renewal application for Peach Bottom would likely facilitate strategic harvesting of materials from permanently shut down reactors as well as the strategic collection of materials routinely removed from operating reactors. The corrected subsequent license renewal application would identify which aging management programs are vulnerable to loss of operating experience information as reactors permanently shut down, thus revealing the priorities for harvesting and collecting materials.

To illustrate the context of the SLR application's failing, consider two cases: (1) aging management programs relying primarily on results from periodic tests and inspections at Peach Bottom, supported by results from tests and inspections at other reactors; and (2) aging management programs relying primarily on results from tests and inspections at other reactors, backed by results from tests and inspections and Peach Bottom. The closure of several, perhaps even many, reactors would have less potential adverse impact on the effectiveness of the Case 1 aging management programs than of the Case 2 programs.

Explicit descriptions of the sources for and volumes of operating experience for the aging management programs is necessary to prevent reactor closures from compromising safety margins. Explicit descriptions are the proper foundations for informed decisions about replacing operating experience reductions as reactors permanently close with expanded inspection efforts at Peach Bottom, broader analyses of materials routinely removed from operating reactors, and/or increased analyses of materials harvested from permanently shut down reactors.

In the past, operating experience came in the form of licensee event reports, NRC inspection reports, vendor advisories, and similar feedback from nearly 100 operating reactors supplemented by insights gained from evaluation of materials collected following routine removals from operating plants and harvested from permanently shut down plants. The flow of operating experience from operating reactors could be significantly reduced as reactors permanently close. When aging management programs rely primarily on feedback from operating reactors for their sustained effectiveness, means must exist to obtain that feedback from alternate sources.

Lacking explicit descriptions, the subsequent license renewal application would be like performing a safety evaluation under 10 CFR 50.59 without an Updated Final Safety Analysis Report (UFSAR) for a proposed modification to the plant or revision to an operating procedure. The UFSAR defines the boundaries of the safety box, enabling the 50.59 evaluation to determine whether the proposed change is, or is not, within those boundaries. The subsequent license renewal application needs to explicitly provide the context for 10 CFR 50.59 evaluations to properly determine whether permanent closures of reactors that reduce the amount of operating experience available also diminishes the effectiveness of aging management programs.

By regulation and by propriety, the reactor operating licenses for Peach Bottom Units 2 and 3 must NOT be renewed until the subsequent license renewal application is revised to contain an explicit discussion of how the aging management programs rely on operating experience to maintain their effectiveness.

9.0 Conclusions

Sections 1.0 through 8.0 of this report identify the following facts and justify the following conclusions:

1. The NRC's license renewal rule requires effective aging management programs for structures, systems, and components important to safety.

2. Operating experience is an integral element of effective aging management programs.

3. The license renewal rule prohibits applications for license renewal from being submitted more than 20 years before the expiration of the reactor operating license for the explicit reason of ensuring sufficient operating experience has accumulated to adequately inform aging management program decisions.

4. The Standard Review Plan for Subsequent License Renewal supplements this front-end provision about operating experience with a requirement that owners use operating experience on an ongoing basis to maintain the effectiveness of their aging management programs throughout the period of extended operation.

5. Deficiencies in the understanding of aging mechanisms are known to exist that need to be addressed by operating experience feedback in the future.

6. The NRC has specifically charged the nuclear industry (which includes Exelon) with responsibility to resolve technical unknowns regarding certain components in order to ensure safe operation during the subsequent license renewal term: reactor pressure vessel embrittlement; irradiation-assisted stress corrosion cracking of reactor internals, concrete structures and containment degradation; and electrical cable qualification and condition assessment.

7. Several reactors have permanently closed in recent years and other reactors may permanently close before the Peach Bottom reactors enter the periods of extended operation sought by the subsequent license renewal application. Few new reactors seem poised to replace those that close.

8. Closure of nuclear power reactors reduces the amount of operating experience available.

9. Industry aging management guidance documents and the subsequent license renewal application for Peach Bottom describe how operating experience will be collected and evaluated on an ongoing basis, but they fail to describe how the amount and source of operating experience collected will be determined to be sufficient to sustain aging management program effectiveness.

10. Insufficient operating experience information could impair the effectiveness of aging management programs and result in structures, systems, and components becoming unable to perform their intended safety functions.

11. Exelon's subsequent license renewal application for Peach Bottom Units 2 and 3 fails to address the sufficiency of operating experience information to inform its aging management programs during the subsequent license renewal terms. Therefore, Exelon does not satisfy the NRC's regulatory requirement to describe how effectiveness of the aging management programs will be assured throughout the proposed periods of extended operation.

12. The operating licenses for Peach Bottom Units 2 and 3 should not be renewed until the applicant provides the following information:

    (a) The degree to which Exelon's aging management programs depend on external operating experience,

    (b) How Exelon will determine what amount of operating experience is sufficient to ensure effectiveness of the programs, and

    (c) How operating experience will be augmented if it is deemed insufficient.

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