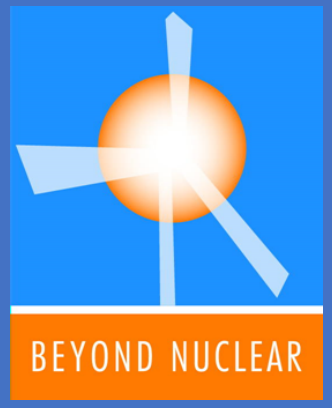
Extending Reactor Licenses to an Extreme

TOPIC #2
Technical Issues for Mechanical Components

JANUARY 21, 2021
PAUL GUNTER
REACTOR OVERSIGHT PROJECT
BEYOND NUCLEAR



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

RIC 2018

Harvesting of Aged Materials from Nuclear Power Plants

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Background and Motivation

Recent developments in the nuclear industry include stronger interest in extended plant operation and plans to shut down a number of nuclear power plants (NPPs). In the United States, there is strong interest in extending NPP lifespans through subsequent license renewal (SLR) from 60 to 80 years.

Extended plant operation and SLR raise a number of technical issues that may require further research to understand and quantify aging mechanisms. U.S. utilities and the U.S. Nuclear Regulatory Commission (NRC) have focused on the aging of systems, structures, and components and in particular four key SLR issues: reactor pressure vessel embrittlement, irradiation-assisted stress-corrosion cracking of reactor internals, concrete structures and containment degradation, and electrical cable qualification and condition assessment.

Meanwhile, in recent years, a number of NPPs, both in the United States and internationally, have shut down or announced plans to shut down for various reasons, including economic, political, and technical challenges. Unlike in the past when there were very few plants shutting down, these new developments provide opportunities for harvesting components that were aged in representative light-water reactor environments.

In a third related development, economic challenges and limited budgets have restricted the resources available to support new research, including harvesting programs. Given this constrained budget environment, aligning interests and leveraging with other organizations is important to allow maximum benefit and value for future research programs.

Current Activities

The NRC has recently undertaken an effort, with the assistance of Pacific Northwest National Laboratory, to develop a strategic approach to harvesting aged materials from NPPs. Because of limited opportunities, past harvesting efforts have been reactive to individual plants shutting down and beginning decommissioning. Given the expected availability of materials from numerous plants and anticipated research needs to better understand aging out to 80 years of operation, the NRC is pursuing a more proactive approach to prioritize the data needs best addressed by harvesting and identify the best sources of materials to address high-priority data needs for regulatory research.

The first step in this strategic approach is to prioritize data needs for harvesting. A data need describes a particular degradation scenario and should be defined with as much detail as appropriate in terms of the material (alloy, composition, etc.) and environment (temperature, fluence, chemistry, etc.).

Potential Criteria for Harvesting Prioritization

A number of criteria may be considered when prioritizing the data needs for harvesting, including the following:

- Applicability of harvested material for addressing critical gaps
  - Harvesting for critical gaps is prioritized over less essential technical gaps.
- Ease of laboratory replication of the degradation scenario
  - For example, simultaneous thermal and irradiation conditions are difficult to replicate, and accelerated aging may not be feasible for a mechanism sensitive to dose rate.
- Unique field aspects of degradation
  - For example, unusual operating experience or legacy material (fabrication methods, etc.) is no longer available.
- Fleet-wide vs. plant-specific applicability of data
  - There is greater value in addressing an issue applicable to a larger number of plants.
- Harvesting cost and complexity
  - For example, harvesting unirradiated concrete or electrical cables is less expensive and less complex than harvesting from the reactor internals or reactor pressure vessel.
- Availability of reliable inservice inspection (ISI) techniques for the material/component
  - If mature inspection methods exist and are easy to apply, harvesting may be less valuable.
- Availability of materials for harvesting
- Timeliness of the expected research results relative to the objective.

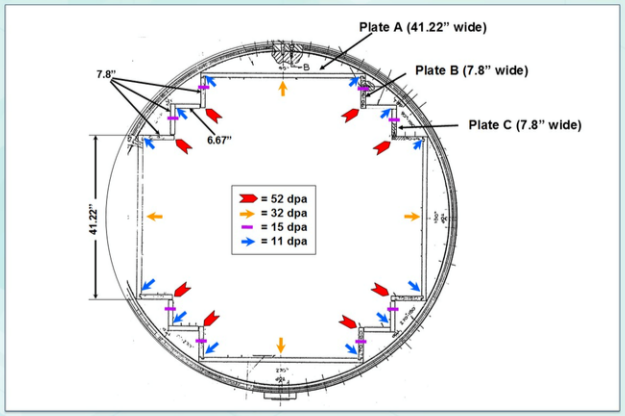
Lifting operation for irradiated materials transport cask

Harvesting Database

The NRC is pursuing the development of a database for sources of materials for harvesting, which could include both previously harvested materials and those available for future harvesting. This database would allow for aligning high-priority data needs to the available sources of materials. The level of detail for the database should be appropriate for the factors influencing decisionmaking. The NRC is interested in engaging with other organizations in developing the database.

Path Forward

In the NRC's experience, harvesting can yield highly representative and valuable data on materials aging, but these efforts will be challenging. Having a clearly defined objective and early engagement with other stakeholders are keys to success. As specific harvesting opportunities are identified through this strategic approach, the NRC welcomes opportunities for cooperation and leveraging of resources with other interested research organizations.



Example of reactor internals harvesting plan

Federal Register, June 21, 1996, pp. 31964-31966

Yankee Atomic Electric Co., Sacramento Municipal Utility District, Portland General Electric Co., and Southern California Edison,: Receipt of Petition and Issuance of NRC Director's Decision under 10 CFR 2.206

April 1, 1996, Nuclear Information Resource Service, Citizens Awareness Network and nine other public organizations requested the NRC to modify the possession only licenses for the Yankee Rowe, Rancho Seco, Trojan and San Onofre Unit 1 nuclear power stations to require a collaborative effort to document and research radiation embrittlement of their respective reactor pressure vessels (RPV) by suspending plans to bury the components until substantial metal and weld samples from the RPVs be harvested for analysis and materially archive the radiation embrittlement phenomenon.

Federal Register, June 21, 1996 (cont.)

"Notice is also hereby given that by a Director's Decision (DD 96-07) dated June 14, 1996, the Director, Office of Nuclear Reactor Regulation, has denied the petition.

"The NRC staff has concluded that sufficient information is already and will be available to the staff to satisfactorily and timely address such radiation embrittlement phenomenon in a manner which protects public health and safety..."

Nevada Department of Transportation

San Onofre Unit 1 reactor pressure vessel (770 tons) was the last of the previously referenced decommissioned reactors to arrive at its permanent burial site in Clive, Utah, July 2020, without being autopsied for archival samples.

ENERGYSOLUTIONS

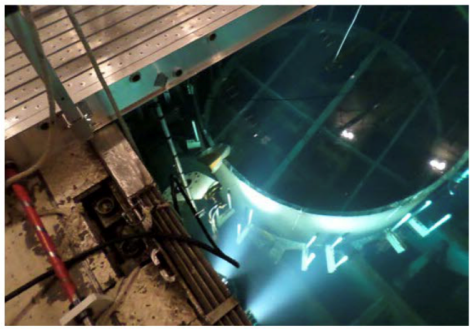
Zion Harvesting Experience and Lessons Learned

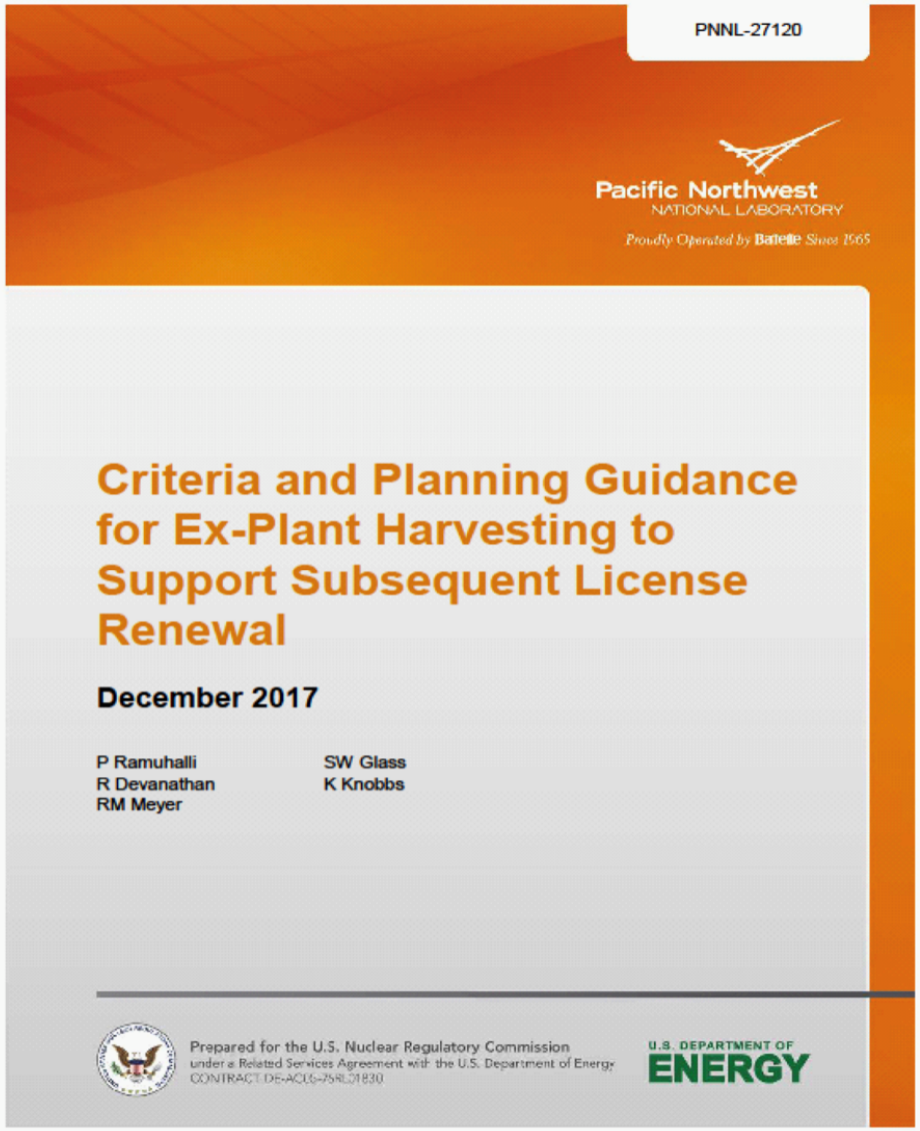
Gerry van Noordennen
March 8, 2017

Successful Harvesting Opportunities Require Clear Scope and Schedule

ENERGYSOLUTIONS

- **Plant View**
  - There is no financial incentive to support harvesting
  - The research agency must be willing to pay for the costs to surgically remove components
  - The research agency must provide a clear scope and schedule at the beginning of the active decommissioning period (DECON)
  - Delays in federal approvals mean lost opportunities





Section 3.4. 2 Cast Austenitic Stainless Steel (CASS)

PNNL–27120 references many "knowledge gaps" identified in the literature including "Expanded Materials Degradation Assessments"(EMDA), NUREG/CR-7153 to include reactor internals.

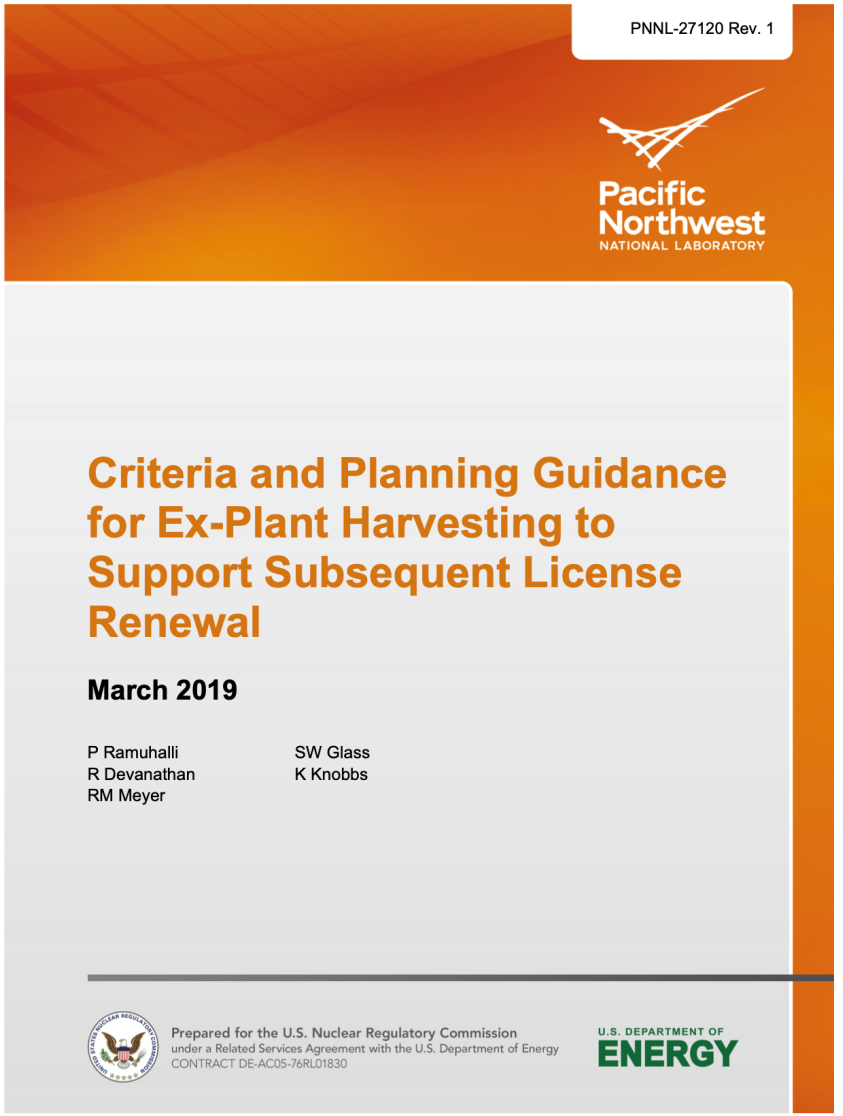
"4. Knowledge gaps: There is data in the literature that suggests significant loss of fracture toughness for neutron exposures between 0.5 and 5 dpa due to the interaction of neutron and thermal embrittlement effects (Chopra 2015). This interaction needs to be understood for life extension."

"5. Harvested materials can be used to address critical knowledge gaps in two areas: (1) calibration and validation of current accelerated testing procedures; and (2) assessment of the combined effects of thermal aging, coolant effects, and neutron irradiation. Degradation initiation and growth studies can be conducted with harvested materials. New/improved ISI procedures may be developed to detect degradation."

The two references to "knowledge gaps" in Subsequent License Renewal Reviews were among numerous other references removed by the NRC revision of the federal laboratory report [PNNL 27120 Rev. 1].

Other revisions from the December 2017 published version that was pulled by NRC from three government websites further toned down findings that would "require" strategic harvesting of "real world" aged materials for analysis.

Other findings such as "benchmarking of laboratory tests will require harvesting materials from reactors" were toned down to "harvesting would allow calibration of accelerated aging in the laboratory against long-term service in a reactor environment" in PNNL-2712 Rev.1.



PNNL-27120 Rev. 1

Pacific Northwest
NATIONAL LABORATORY

Criteria and Planning Guidance for Ex-Plant Harvesting to Support Subsequent License Renewal

March 2019

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R Devanathan
RM Meyer
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Prepared for the U.S. Nuclear Regulatory Commission
under a Related Services Agreement with the U.S. Department of Energy
CONTRACT DE-AC05-76RL01830

U.S. DEPARTMENT OF ENERGY

"Expanded Materials Degradation Assessments"(EMDA), NUREG/CR-7153, Volume 2, Aging of Core Internals and Piping Systems, Oct. 2012

The term "knowledge gaps" is used 40 times in EMDA just in Volume 2.

For example, "*The extent of knowledge gaps is impacted by the unknowns associated with synergisms between different degradation modes; for instance, the effort on SCC* (stress corrosion cracking) *of irradiation damage and thermal embrittlement, which are very time dependent.*" [p. 305]

Obviously, concern over how many times the term "knowledge gap" appears in technical documents used to qualify for license extension, of any duration, does not constitute adequate reason to scrub those determinations without also providing "if and how" those findings were addressed. Yet, "messaging" appears to have played a significant role in the NRC revision of the federal laboratory's Technical Letter Report PNNL-27120 to PNNL-27120 Rev. 1.

This type treatment does not build public confidence in the technical review of age management programs, particularly as operating license extensions become more and more extreme.