NRC Harvesting Strategy, Coordination, and Activities

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Harvesting Public Meeting

Outline

- Background
- Strategy
  - Priorities
  - Previously Harvested Materials
  - Opportunities
- Recent and Current Activities
- Coordination

Materials Harvesting Background

- Historically, NRC, industry and others have performed research on materials harvested from a broad range of components
- Current harvesting objectives focus on materials aging during long-term operation:
  - Confirm results from laboratory experiments and analytical simulations to improve understanding of aging during highly representative service conditions
  - Reduce uncertainty in current state of knowledge of aging and NDE effectiveness to enable informed NRC review of aging management programs

Figure: Control rod drive mechanism (CRDM) Nozzle 63 from the North Anna Unit 2 reactor (NUREG/CR-7142)

Current Situation

- In the past, harvesting efforts have generally been reactive as limited new opportunities arose
  - Few plants shutting down led to more “demand” than “supply”
- In recent years, a significant number of plants have shut down and entered the decommissioning process
  - Generally operated for a long period, which provides more highly aged components for harvesting
  - Currently more “supply” of harvesting opportunities than in the past
- Current situation calls for a more proactive strategic approach

A Strategic Approach to Harvesting

- In 2015, NRC began an effort to develop a materials harvesting strategy
  - NRC previously was very reactive to harvesting opportunities
  - PNNL developed a report to help inform a harvesting strategy
- Harvesting challenges
  - Expensive, complex, and time-consuming (particularly with irradiated materials)
  - Documentation of component fabrication and aging conditions
  - Decommissioning vs. harvesting

- **Strategy:** Focus on high-value harvesting opportunities
  - Seek cooperation when possible to maximize limited NRC resources

Proactive Harvesting Strategy

1. Identify and prioritize harvesting interests

- Focused on the unique value of harvesting relative to other sources of information (e.g. accelerated aging, operating experience)

2. Consider use of previously harvested materials when possible

- Greatly reduced cost, time and complexity compared to new harvesting
- Limited in the range of materials and aging conditions represented

3. Gather information on harvesting opportunities

- Requires sufficient information to meaningfully compare to priorities
- Challenging to acquire across the population of decommissioning plants

Harvesting Interests Prioritization

- Identify and prioritize materials degradation issues best addressed by harvesting to focus limited resources on highest priority needs
- NRC staff performed review to prioritize harvesting interests for various components (metallic, electrical, and concrete)
  - Identified interest by component / material, purpose or planned testing and knowledge to be gained
  - Ranked harvesting interests by technical criteria relevant to NRC mission and priorities
  - Binned interests based on results from ranking criteria

Technical Prioritization Criteria

Criticalness of Technical Issue Addressed

- Higher safety significance and less available data leads to higher ranking

Importance of Harvested Materials over Laboratory Aging

- In-plant aging conditions or materials that are more difficult to replicate in the lab leads to higher ranking

Applicability to US Operating Fleet

- Applicability to a greater number of plants leads to higher ranking

Regulatory Considerations Related to Inspections and AMPs

- Greater availability and confidence in inspection methods or aging management approaches leads to lower ranking

High Priorities - Metals

Interest Description	Purpose / Testing Planned	Technical Knowledge Gained	Harvesting Status
600 thermally treated (TT) steam generator (SG) tubes with shallow flaws	Non-destructive examination (NDE) and mechanical testing	NDE assessment / detection and structural integrity for shallow flaws	Seeking opportunities
Thermally aged unirradiated cast stainless steel (CASS)	Fracture toughness and microstructure	Fracture toughness data in real conditions to compare to accelerated aging data	Identified and pursuing opportunity
Bottom-mounted instrumentation (BMI) nozzles with known PWSCC indications	Residual stress measurements and crack initiation/growth testing	Confirm adequacy of current inspection requirements	Seeking opportunities – very few plants with known BMI indications
	Flaw characterization	Confirm NDE effectiveness and flaw distribution	
Higher fluence stainless steel (SS) welds (>2 dpa)	Fracture toughness, IASCC CGR, and microstructure	Properties to inform inspection scope and interval and flaw evaluation	Addressed by SMILE* and other opportunities
Very high fluence SS welds from CE plants (>10 dpa)	Fracture toughness, IASCC, and microstructure	Properties to inform inspection scope and interval and flaw evaluation	Identified and pursuing opportunity

*SMILE = Studsvik Materials Integrity for Life Extension

High Priorities - Concrete/Structural and Electrical

Interest Description	Purpose / Testing Planned	Technical Knowledge Gained	Harvesting Status
Irradiated concrete	Real life data, model verification. Mechanical properties and characterization. Potential further irradiation.	Damage characterization, model Verification, reduce uncertainty, evaluate structural performance. Gain insight for rate effects, scale effects compared to accelerated testing.	Identified and pursuing opportunity.
Reactor supports	Embrittlement, fracture toughness, microstructure	Structural integrity and performance. Inform inspection scope.	Identified and pursuing opportunity.
Electrical Cables (low and medium voltage)	Comparison of service aged specimen with accelerated-aged samples. Assess NDE effectiveness. Assess fire spread and thermal failure criteria.	Confirm technical basis for aging management programs.	Seeking opportunities.

Previously Harvested Materials

- NRC staff have catalogued previously harvested materials from prior NRC-sponsored research, including:
  - PNNL – large array of components from smaller penetrations up to large piping sections used for NDE research
  - Battelle – large primary system piping and elbows
  - ANL – smaller irradiated reactor internals materials
- Other sources of previously harvested materials:
  - U.S. Department of Energy (DOE) Nuclear Fuels and Materials Library (NFML)
  - Studsvik – SMILE-related and other harvested materials
  - Halden Reactor Project

Examples from PNNL

Harvesting Opportunities

- NRC has worked with EPRI to develop a harvesting opportunities table
  - Covers domestic and international harvesting opportunities (decommissioning or announced shutdown date plants)
- Examples of column headings shown below:

Plant	Utility	Design	Size (MWe)	Core Inlet / Outlet Temp (°C)	Years in operation	Shutdown Date	Harvesting or Decommissioning Plan / Timeline	Research Organizations	Summary of Components Previously Discussed

RPV Beltline			PWR RPV Head Penetrations / BWR Instrumentation Penetrations			Baffle Plate			Internals Bolts			Core Shroud / Barrel Welds		
Material (Alloy & Fabrication Method)	Environment (dpa, temp, water chemistry)	OpE or other info	Material (Alloy & Fabrication Method)	Environment (EFPY, temp, water chemistry)	OpE or other info	Material (Alloy & Fabrication Method)	Environment (dpa, temp, water chemistry)	OpE or other info	Material (Alloy & Fabrication Method)	Environment (dpa, temp, water chemistry)	OpE or other info	Material (Alloy & Fabrication Method)	Environment (dpa, temp, water chemistry)	OpE or other info

Recently Shutdown U.S. Plants

Plant	Design	Size (MWt)	Years in Operation	Shutdown Date
SONGS 2/3	PWR (CE)	3,438	31/30	2012
Kewaunee	PWR (W 2-loop)	1,772	39	2013
Crystal River 3	PWR (B&W)	2,609	36	2013
Vermont Yankee	BWR-4/Mark-1	1,912	42	2015
Fort Calhoun	PWR (CE)	1,500	43	2016
Oyster Creek	BWR-2/Mark-1	1,930	49	2018
Pilgrim	BWR-3/Mark-1	2,028	47	2019
Three Mile Island 1	PWR (B&W)	2,568	45	2019
Indian Point 2/3	PWR (W 4-loop)	3,216	48/46	2020/2021
Palisades	PWR (CE)	2,565	51	2022
Diablo Canyon 1/2	PWR (W 4-loop)	3,411	40	2024-5*

*planned shutdown date

Harvesting Coordination

- For harvesting cooperation and leveraging, coordination with potential partners is essential
- Past NRC cooperation on harvesting has involved:
  - U.S. Department of Energy (DOE)
  - Electric Power Research Institute (EPRI)
  - International partners
- Coordination has occurred via recurring calls and meetings with domestic and international researchers

Recent and Current Harvesting Activities

Plant	Components Harvested	Status
Bellefonte	Electrical enclosures	NUREG-2180; NUREG/CR-7197
Zion	Neutron absorber materials	ML19155A215
	Electrical cables	Testing ongoing
	Electrical bus ducts	OECD/NEA/CSNI/R(2017)7
Crystal River 3	Electrical bus ducts	Testing planned
Zorita	Reactor internals	ML22132A039; ML20198M503
SONGS 2	Unirradiated concrete	ML22119A092
Ringhals 2	RPV, internals, RPV penetrations, SG tubes, piping	OECD/NEA SMILE ongoing through 2025
Oskarshamn	RPV, internals, piping	

Path Forward

- NRC will maintain and update as appropriate its harvesting priorities and seek opportunities that align with priorities
- Studsvik Materials Integrity for Life Extension (SMILE) project continues through 2025
  - Covers a wide variety of metallic components
- Pursuing harvesting opportunities from domestic and international sources in accordance with the harvesting strategy
- NRC staff are expecting to brief the Advisory Committee on Reactor Safeguards (ACRS) on harvesting activities in fall 2022

Acronym List

- ANL Argonne National Laboratory
- B&W Babcock and Wilcox
- BWR Boiling water reactor
- CE Combustion Engineering
- CGR Crack growth rate
- DOE Department of Energy
- EPRI Electric Power Research Institute
- FT Fracture toughness
- HAZ Heat-affected zone
- HWC Hydrogen water chemistry
- IASCC Irradiation-assisted stress corrosion cracking
- INL Idaho National Laboratory
- MRP Materials Reliability Program
- NMCA Noble metal chemistry addition
- MWt Megawatt-thermal
- NEA Nuclear Energy Agency
- NWC Normal water chemistry
- OECD Organization for Economic Co-operation and Development
- PNNL Pacific Northwest National Laboratory
- PWR Pressurized water reactor
- PWSCC Primary water stress corrosion cracking
- RPV Reactor Pressure Vessel
- SCC Stress corrosion cracking
- SEM Scanning electron microscopy
- SMILE Studsvik Materials Integrity for Life Extension
- SS Stainless steel
- TEM Transmission electron microscopy