

NRC Materials Research for Aging Management

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**PUBLIC MEETING ON DEVELOPMENT OF GUIDANCE DOCUMENTS TO SUPPORT
LICENSE RENEWAL FOR 100 YEARS OF PLANT OPERATION**

January 21, 2021

NRC Headquarters Rockville, MD (Virtual meeting)

Materials and Aging Research

- Research Objectives
 - Improve timeliness of regulatory decision-making on the use of new materials, manufacturing technologies, and in-service inspection techniques through independent and confirmatory research
 - Address materials degradation during long-term plant operation
 - Inform and enhance the use of risk information in regulatory decision-making
- Strategic Focus Areas
 - Support resolution of safety significant technical issues
 - **Maintain core capabilities to support emerging technical needs related to corrosion, metallurgy, component integrity assessment, and non-destructive examination**
 - Enhance modeling/analytical tools to support efficient regulatory decision-making
 - Foster collaborations with domestic and international counterparts to stimulate information sharing and cooperative research approaches
- High level summary of activities follows: More information contained in NUREG-1925 [ML18091A139]

Long-Term Operation (LTO) & Aging Management

- Overview
 - **Objective:** Support guidance development, coordinate related research activities, develop a systematic approach for harvesting materials and components from reactors
 - **Motivation:** Provide reasonable assurance that aging effects will be adequately managed during LTO
 - **Regulatory Application:** Refine, as appropriate, existing aging management programs and guidance
 - **Collaboration:** DOE and EPRI
- Status of current activities
 - International workshops held on metals (2019) and cables (2020) aging management
 - Coordinating with research counterparts on metals aging research (RPV, internals, piping)
 - Coordinating with research counterparts on concrete aging research (irradiation, modeling, NDE)
 - Coordinating with research counterparts on cable aging research (irradiation, thermal aging, condition assessment)
- Planned research activities
 - Continuing international communications to coordinate harvesting opportunities and priorities
 - Considering an international workshop on concrete aging (2022)



Research Partnerships

- Motivation
 - Harvesting and research related to nuclear safety is typically complex, costly, and lengthy, especially if the activity involves irradiated material
 - Research activities are prioritized to address potential safety-significant technical issues
 - Most efficient use of taxpayer investment often requires coordination and collaboration with other stakeholders
- Domestic Partners
 - Nuclear research organizations – EPRI and DOE laboratories
 - Rich variety – Academia, nuclear vendors, owner’s groups, technical support organizations, other government agencies
- International Partners
 - Nuclear plant regulators and technical support organizations
 - Often collaborate through IAEA or NEA, but also through direct agreements
- Partnerships are identified for specific activities on subsequent slides



Ex-Plant Materials Harvesting

- Overview

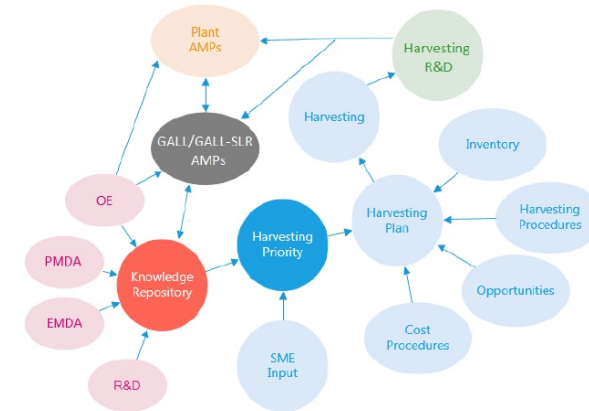
- **Objective:** Improve understanding of material degradation associated with LTO
- **Motivation:** Harvested materials can confirm information on aging mechanisms generated through other research programs and operating experience
- **Regulatory Application:** Inform aging management approaches to ensure they are appropriate and adequate
- **Collaboration:** DOE, EPRI, OECD/NEA, other international partners

- Status of current activities

- Several activities are incorporating harvested components in their research plans
- NRC has identified broad harvesting priorities and possible harvesting opportunities
- Research interests encompass metals, concrete, and electrical / cables components
- NRC is coordinating with DOE and EPRI to explore opportunities that may align with NRC's research interests

- Planned research

- Initiate participation in OECD/NEA project to perform harvesting of metallic components (2021 – 2025)
- Support DOE efforts to acquire irradiated materials samples from the Halden Reactor Project for the DOE Nuclear Fuels and Materials Library (2022 – 2024)
- Pursue opportunities, in coordination with partners, for harvesting components from decommissioning U.S. and international plants (ongoing)



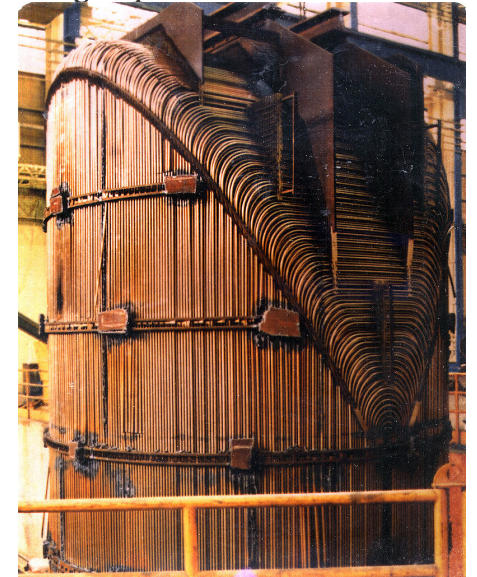
Primary Water Stress Corrosion Cracking (PWSCC)

- Overview
 - **Objective:** Evaluate PWSCC crack initiation and crack growth rate (CGR) susceptibility of nickel-based alloys
 - **Motivation:** Provide assurance of reactor coolant pressure boundary integrity
 - **Regulatory Application:** Support reviews of proposed changes to the inspection requirements in the ASME Code and associated rulemaking
 - **Collaboration:** EPRI
- Status of current activities
 - Recently completed 20 years of CGR testing of Alloys 600/82/182 and Alloys 690/52/152 at ANL and PNNL
 - Data used to evaluate requests for new component inspection requirements and ASME Code actions
 - Developing PWSCC initiation data on Alloys 600/182 and Alloys 690/52/152 to verify probabilistic modeling parameters/dependencies and potential factors of improvement
- Planned research
 - Complete literature survey and action plan to determine potential research needs (2021)
 - Complete crack initiation testing, analyze test results, document results (2022 – 2023)



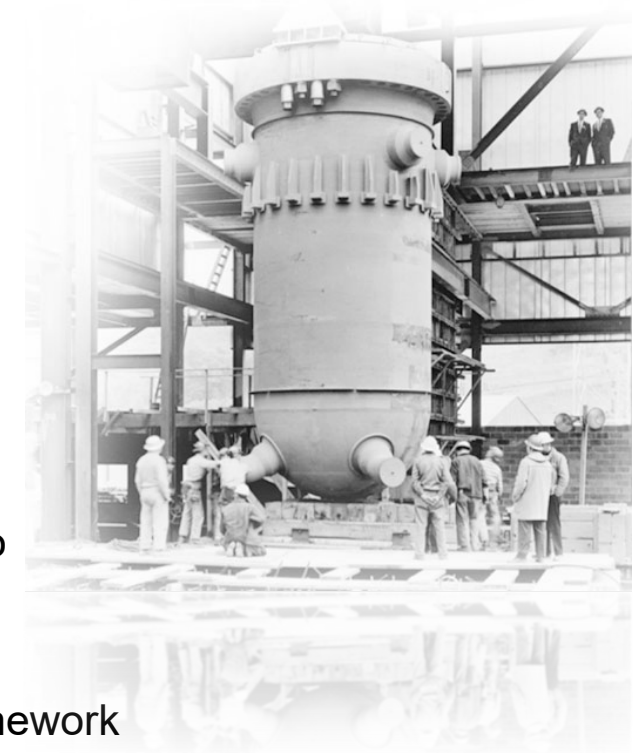
Steam Generator Tube Integrity Program (SG-TIP)

- Overview
 - **Objective:** Assess NDE reliability and associated tube integrity for emerging inspection procedures and plans
 - **Motivation:** Confirm adequacy of industry practices used for in-service inspection
 - **Regulatory Application:** Review acceptability of advanced techniques or implementation plans proposed by industry
 - **Collaboration:** EPRI, CNSC, KINS, KAERI, GRS, and IRSN
- Status of current activities
 - Complete report summarizing eddy current inspections and pressure testing of U-bend tubes with PWSCC flaws
 - Complete report on detection of cracking near volumetric indications
 - Developing the regulatory analysis of industry's proposed tech spec changes for extending the ISI interval
- Planned research
 - Evaluate new lab inspection results related to eddy current detection and sizing
 - Re-evaluate the 2016 NUREG/CR for auto-analysis techniques
 - Work with our international partners to incorporate improved inspection and analysis procedures



Reactor Pressure Vessel (RPV) Integrity

- Overview
 - **Objective:** Assess embrittlement prediction formulas, improve fluence calculations and evaluate structural integrity challenges
 - **Motivation:** Confirm continued integrity of RPV during LTO
 - **Regulatory Application:** Enhance guidance for RPV structural integrity and fluence calculations
 - **Collaboration:** JNRA
- Status of current activities
 - Completed scoping study that evaluated the impacts of ETC under-predictions to support decision to not revise RG 1.99.
 - Completing the alternative embrittlement trend curve (ETC) basis report
 - Completing a holistic safety review to evaluate efficacy of current regulatory framework
- Planned research
 - Document fluence calculation methodology study for extended beltline and reactor internals (2021)
 - Complete shallow flaw structural integrity investigation (2020 - 2021)



Piping Integrity

- Overview
 - **Objective:** Develop and enhance analytical methods and tools to assess structural integrity of reactor piping systems
 - **Motivation:** Confirm continued integrity of safety-critical piping systems during LTO
 - **Regulatory Application:** Enhance guidance for performing piping structural integrity calculations
 - **Collaboration:** EPRI and CSNI
- Status of current activities
 - Recently published NUREG-2228 on weld residual stress validation
 - Completed CSNI benchmark report on Extended Finite Element Modeling (xFEM)
 - Investigated and developed xFEM techniques for PWSCC modeling
 - Completed phase 1 of CSNI Leak rate and Leak-before-break (LBB) benchmarks; phase 2 for both is ongoing
 - Research on Structural Integrity and NDE of CFRP Repair & Risk Significance and Consequences of Fiber Reinforced Plastic Repair of Degraded Piping
- Planned research
 - Issue update to NRC's leak rate code, LEAPOR-SA v1.0 (2021)
 - Complete CSNI leak rate and LBB benchmark exercises (2021)
 - Complete CFRP repair adjustment factor testing and risk significance study (2021-2022)



Irradiation-Assisted Degradation (IAD)

- Overview
 - **Objective:** Evaluate irradiation assisted degradation mechanisms during LTO
 - **Motivation:** Confirm adequacy of reactor internals aging management programs
 - **Regulatory Application:** Support reviews of internals inspection/ evaluation guidance, ASME Code changes and associated rulemaking
 - **Collaboration:** EPRI, OECD/NEA
- Status of current research
 - Recently completed cooperative research supporting testing of materials harvested from Zorita reactor
 - Assessing further independent testing of Zorita materials at ANL
- Planned research
 - Complete independent testing and assessment of research on Zorita reactor internal materials (2021)
 - Initiate participation in OECD/NEA projects to perform harvesting and test reactor irradiation experiments on irradiated materials (2021 – 2023)



Nondestructive Evaluation (NDE)

- Overview
 - **Objective:** Evaluate effectiveness and reliability of NDE techniques
 - **Motivation:** Confirm adequacy of industry procedures and practices
 - **Regulatory Application:** Support reviews of ASME Code modifications and proposed revisions of current requirements
 - **Collaboration:** EPRI, IRSN, and PIONIC
- Status of current activities
 - Completed report on modeling & simulation of austenitic welds and coarse-grained specimens
 - Completed evaluation of flaw detectability under limited-coverage conditions
 - Completed baseline evaluation of eddy current testing for PWSCC-susceptible materials
 - Completed report on NDE reliability issues for the examination of CASS components
- Planned research
 - Develop technical basis to support guidance for UT Modeling & Simulation (2021-2022)
 - Evaluate the effects of incomplete examination coverage (2021-2022)
 - Evaluate Advanced NDE Techniques (2021 - 2023)
 - Assess the capabilities of machine learning and automated data analysis in NDE (2021 – 2023)



Summary

- NRC conducts confirmatory research to establish technical bases that support regulatory decisions and development of regulatory guidance documents
- NRC staff exchanges information with domestic and international counterparts on materials performance and aging management of nuclear power plant structures and components, and conducts independent analyses
 - Research results
 - Operating experience
- Research activities are prioritized to address potential safety-significant technical issues
- Long-lead-time confirmatory research is an important consideration in proactive aging management

Abbreviations

AMP	Aging management program	KAERI	Korea Atomic Energy Research Institute
ANL	Argonne National Laboratory	KINS	Korea Institute of Nuclear Safety
ASME	American Society of Mechanical Engineers	LBB	Leak before break
CASS	Cast austenitic stainless steel	LTO	Long-term operation
CFRP	Carbon fiber reinforced polymer	NDE	Non-destructive examination
CGR	Crack growth rate	NEA	Nuclear Energy Agency
CNSC	Canadian Nuclear Safety Commission	NEI	Nuclear Energy Institute
CSNI	Committee on the Safety of Nuclear Installations	OECD	Organisation for Economic Cooperation and Development
DOE	U.S. Dept. of Energy	PEO	Period of extended operation
EPRI	Electric Power Research Institute	PIONIC	Program for Investigation Of NDE by International Collaboration
GALL	Generic Aging Lessons Learned	PNNL	Pacific Northwest National Laboratory
GRS	German Society for Plant and Reactor Safety	PWSCC	Primary water stress corrosion cracking
IAD	Irradiation-assisted degradation	RG	Regulatory Guide
IAEA	International Atomic Energy Agency	RPV	Reactor pressure vessel
IRSN	Institute for Radiological Protection and Nuclear Safety	SLR	Subsequent license renewal
ISG	Interim Staff Guidance	TLAA	Time-limited aging analysis
ISI	In-service inspection	UT	Ultrasonic test
JAEA	Japan Atomic Energy Agency	xFEM	Extended Finite Element Modeling
JNRA	Japan Nuclear Regulation Authority		

BACKUP SLIDE

Probabilistic Structural Integrity (PSI)

- Overview
 - **Objective:** Develop probabilistic methods to assess structural integrity of primary coolant pressure boundary (PCPB) components
 - **Motivation:** Confirm continued integrity of safety-critical piping systems during LTO
 - **Regulatory Application:** Develop guidance for performing probabilistic structural integrity analyses, risk inform regulatory decision-making on component integrity
 - **Collaboration:** EPRI, JNRA, JAEA, SSM, CNSC
- Status of current activities
 - Publicly released the Extremely Low Probability of Rupture (xLPR) code
 - Completed initial probabilistic leak-before-break assessments
- Planned research
 - Complete new FAVOR Software QA Plan and FAVOR Configuration Management Maintenance Plan (2021)
 - Publish xLPR NUREG (2021)
 - Complete draft PSI regulatory guide with supporting technical basis report (2021)
 - Complete studies on leak-before-break applications with xLPR (2021)
 - Finish FAVOR modernization (2022)

