Harvesting
An Overview and Historical Perspective

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Public Meeting on Harvesting
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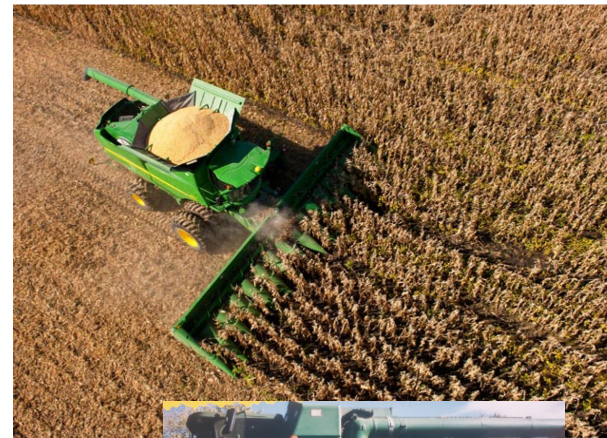
Definitions and meeting scope



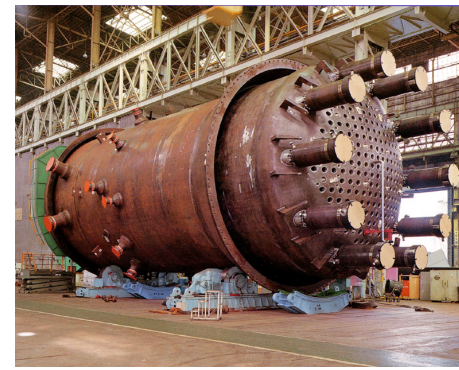
- *Harvesting (v, adj)* – removal of materials, components, or structures (MCS) from a commercial nuclear power plant (NPP) for the purpose of performing subsequent evaluations
- *Mock-ups (n, adj)* – Components produced to simulate NPP component geometries, fabrication, or repair techniques
- *Surveillance Specimens (n)* – Sacrificial test articles placed within an operating NPP that are intended for subsequent removal to evaluate age-related degradation
- *Archival Material (n)* – Remaining excess material from the fabrication of an NPP component

Role of harvesting in aging management

Knowledge gained through harvesting is but one facet that can support effective aging management…

Types of harvesting

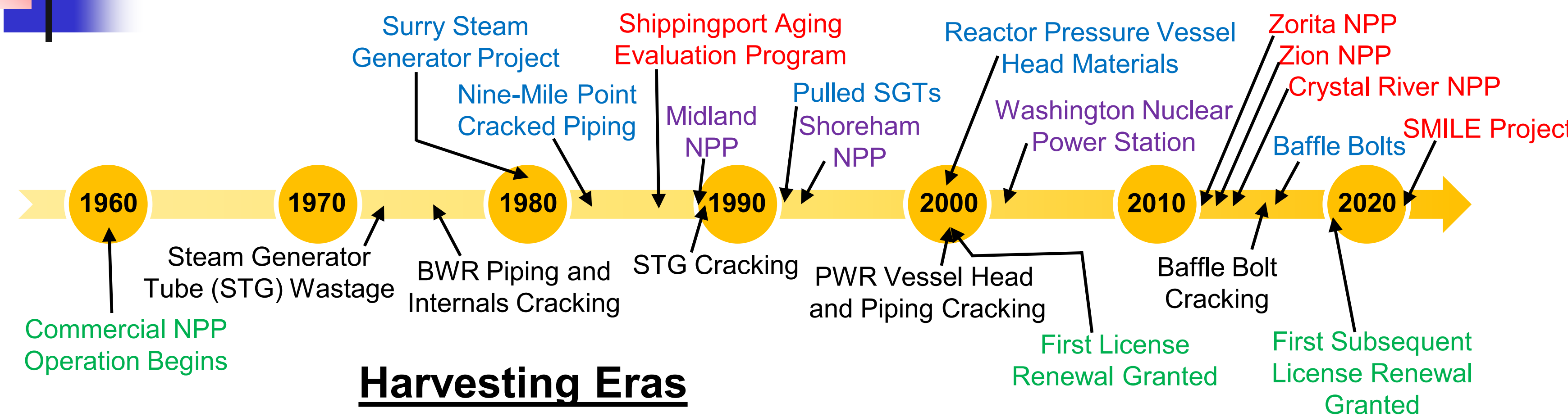
Harvesting can occur in one of three phases of an MCS's life



- Pre-Service
  - **Motivation:** Understand initial performance and/or characteristics of an as-fabricated MCS
  - Possible when NPPs have been partially or fully constructed, but not operated
- During Service
  - **Motivation:** Evaluate current performance and/or characteristics of an MCS or evaluate the root cause of service-induced degradation
  - Possible when an MCS is removed from service prematurely due to unanticipated age-related degradation

- Post-Service
  - **Motivation:** Evaluate an MCS at the end of its service life to understand the progression of age-related degradation
  - Possible when components are replaced or when NPPs permanently shut-down

An abbreviated history of nuclear harvesting



Harvesting Eras

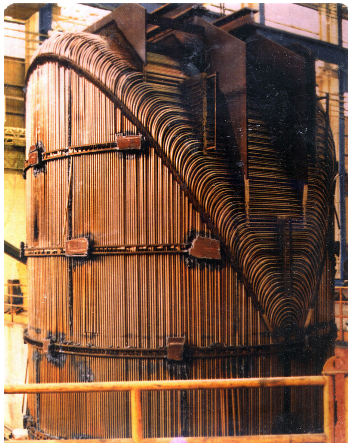
- In the Beginning (1970 – 1990)
  - Limited opportunities
  - Some prematurely replaced components
- Mature Operations (1990 – 2010)
  - Several canceled plants
  - Occasional degraded components
- Current Situation (after 2010)
  - Supply outstrips demand
  - Increased importance of partnering

Timeline Legend

- Canceled NPPs
- Degraded/Replaced Components
- Shut-Down NPPs

A few early harvesting vignettes

- Surry Steam Generator Project
  - Objectives:
    - Validate integrity assessment by burst testing service-degraded specimens
    - Evaluate reliability of techniques to detect, characterize and size degradation
  - International consortium of government and industry organizations
  - More Information: NUREG/CR-5117



- Shippingport Aging Evaluation Program
  - Objective: Evaluate aging effects of components and specimens from the decommissioned Shippingport PWR
  - Evaluated over 200 components (e.g., battery chargers, valves, a motor control center) and specimens (e.g., from neutron shield tank, concrete, cast stainless steel components, piping)
  - More Information: NUREG-1144, Rev. 2
- Midland Reactor Pressure Vessel
  - Objective: Evaluate unirradiated and irradiated properties of a low-upper-shelf energy reactor pressure vessel weld material
  - RPV head was used as an interim replacement for Davis-Besse head
  - More Information: NUREG/CR-5736

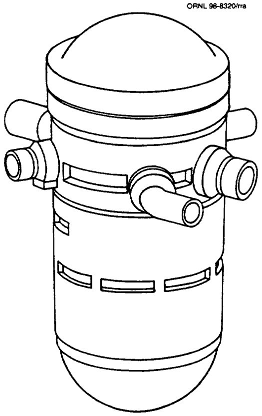


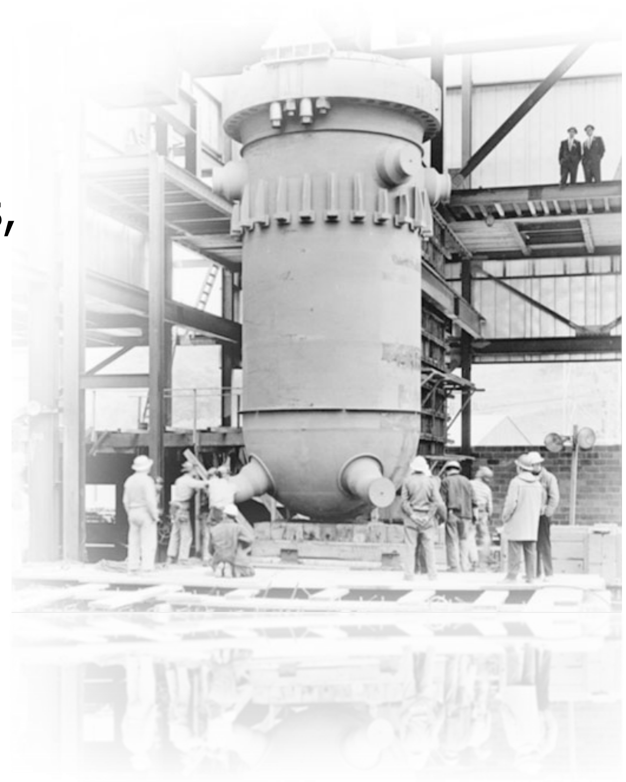
Figure 1. Sampling locations in the Midland Unit 1 reactor pressure vessel.

Some regulatory success stories

- Generic Aging Lessons-Learned report (LR, SLR)
  - Identifies which existing plant programs are adequate for aging management and recommends specific areas where these programs should be augmented
  - One acceptable way to manage aging effects for long-term operation
  - **Role of harvesting**: Supported development of mechanical, structural, electrical AMPs and identification of those areas needing further evaluation
- Alternate Pressurized Thermal Shock (PTS) Rule (10 CFR 50.61a)
  - Voluntary rule provides alternative fracture toughness requirements for demonstrating adequate protection against PTS events
  - **Role of harvesting**: Underpinned much of the basis for underlying flaw distribution, crack initiation, through-wall cracking, and nucleonics models
- Reactor pressure vessel head inspections (10 CFR 50.55a)
  - Requirements for visual, volumetric, and surface examinations of penetrations
  - **Role of harvesting**: Provided confirmation that inspection frequencies are adequate to manage degradation

Summary

- Nuclear stakeholders have actively employed harvesting since the inception of commercial nuclear power plant operation to better understand performance of important materials, components, and structures
- Knowledge gained through harvesting is one facet that can support effective aging management
- While we are entering a new phase where harvesting supply is greater than demand, strategic use of harvesting will continue to play an important role to support long-term nuclear power plant operation



A sampling of harvesting related reports…

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2. Kurtz, R. J., et al. 1990. Steam Generator Integrated Program/Stream Generator Group Project, Final Project Summary Report, **NUREG/CR-5117**, PNL-6226. Prepared for the U.S. Nuclear Regulatory Commission (NRC) by Pacific Northwest Laboratory, Richland, Washington.
3. O.K. Chopra, and W.J. Shack, *Mechanical Properties of Thermally Aged Cast Stainless Steels from Shippingport Reactor Components,* **NUREG/CR-6275** (ANL-94/37), U.S. Nuclear Regulatory Commission, April 1995.
4. G. J. Schuster, S. R. Doctor, S.L. Crawford, and A. F. Pardini, *Characterization of Flaws in U.S. Reactor Pressure Vessels: Density and Distribution of Flaw Indications in the Shoreham Vessel*, **NUREG/CR-6471 Volume 3**, U.S. Nuclear Regulatory Commission, November 1999.
5. G. J. Schuster, S. R. Doctor, A.F. Pardini, and S.L. Crawford, *Characterization of Flaws in U.S. Reactor Pressure Vessels: Validation of Flaw Density and Distribution in the Weld Metal of the PVRUF Vessel*, **NUREG/CR-6471 Volume 2**, U.S. Nuclear Regulatory Commission, August 2000.
6. D.E. McCabe, et al. *Evaluation of WF-70 Weld Metal From the Midland Unit 1 Reactor Vessel*, **NUREG/CR-5736** (ORNL/TM-13748), U.S. Nuclear Regulatory Commission, November 2000.
7. A.B. Johnson, Jr., S.K. Sundaram, F.A. Garner, *Program Plan for Acquiring and Examining Naturally Aged Materials and Components for Nuclear Reactors*, **PNNL-13930**, Pacific Northwest National Laboratory, December 2001. (Prepared for the U.S. Department of Energy).
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9. S.E. Cumblidge, et al. *Nondestructive and Destructive Examination Studies on Removed-from-Service Control Rod Drive Mechanism Penetrations*, **NUREG/CR-6996**, U.S. Nuclear Regulatory Commission, July 2009.

A further sampling of harvesting related reports…

10. S.E. Cumblidge, et al. *Evaluation of Ultrasonic Time-of-Flight Diffraction Data for Selected Control Rod Drive Nozzles from Davis Besse Nuclear Power Plant*, **PNNL-19362**, Pacific Northwest National Laboratory, April 2011.
11. S.L. Crawford, et al. *Ultrasonic Phased Array Assessment of the Interference Fit and Leak Path of the North Anna Unit 2 Control Rod Drive Mechanism Nozzle 63 with Destructive Validation*, **NUREG/CR-7142** (PNNL-21547), U.S. Nuclear Regulatory Commission, August 2012.
12. R. Fuentes, et al. *Characterization and Analysis of Boral from the Zion Nuclear Power Plant Spent Fuel Pool*, SRNL-TR-2018-00244, Rev. 0, Savannah River National Laboratory, March 2019 (**ML19155A215**).
13. P. Ramuhalli, et al. *Criteria and Planning Guidance to Ex-Plant Harvesting to Support Subsequent License Renewal*, PNNL-27120, Rev. 1, Pacific Northwest National Laboratory, March 2019 (**ML19081A006**).
14. Y. Chen, et al. *Crack Growth Rate and Fracture Toughness Tests on Irradiated Ex-Plant Materials*. ANL-19/45, Argonne National Laboratory, July 2020 (**ML20198M503**).
15. Chen, Y., W-Y. Chen, and B. Alexandreanu, “Irradiated Microstructure of Zorita Materials,” ANL-20/50, Argonne National Laboratory, Lemont, IL, August 2020. (**ML20269A143**)
16. Kombaiah, B., C. Judge, J. Charboneau, S. Smith, L. Gimenes Rodrigues Albuquerque, and V. Montes de Oca Carioni, “Chemical Compositional Analysis and Microstructural Characterization of Harvested Zorita Reactor Pressure Vessel (RPV) Internals,” INL/EXT-21-62220, Idaho National Laboratory, Idaho Falls, ID, March 2021. (**ML21124A112**)
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